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Individual Differences Underlying Pilot Cockpit Error

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16. Abstract

Pilot error is cited as the cause of over 80 percent of aviation accidents. As technology renders aircraft more mechanically reliable and provides advanced automation in the cockpit, the rate of human error caused accidents remains stable. This troubling aspect of modern aviation necessitates initiatives to remedy the situation. The present study investigated the relationships between individual difference variables and pilot cockpit error in an attempt to understand the factors that may contribute to accidents caused by human error. It was expected that personality characteristics, individual attitudes, and cognitive ability would affect pilot situational awareness, pilot psychological stress levels, and pilot hazardous thought patterns, which would subsequently affect pilot error type and frequency. Three hundred Army student helicopter pilots were rated on errors during two evaluation check rides. Results indicate inconsistent support for these hypotheses. Situational awareness and psychological stress levels are related to pilot error; however, individual differences that impact the development of situational awareness or that contribute to pilot stress level remain in question.

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INTRODUCTION

This dissertation research focused on individual differences and human performance. Specifically, potential relationships between individual differences and pilot cockpit error were investigated. This research was undertaken based on convergent evidence from industry, government agencies, and the current literature pointing to the immediate and important need to identify factors related to the aircraft mishaps which are attributed to "pilot error." Historically, aspects of aircraft systems design have been and continue to be considered and investigated as potential contributors to mishaps. However, the influence of pilot individual differences on cockpit error has not been afforded equal investigative attention.

Pilot error is consistently cited as a major source of aviation accidents (based on accident data from FAA, NTSB). This human error has accounted for seventy-plus percent of aircraft accidents which result in loss of life and resources for both military and civilian populations. As technological advances have rendered aircraft more reliable, accidents due to mechanical malfunction have

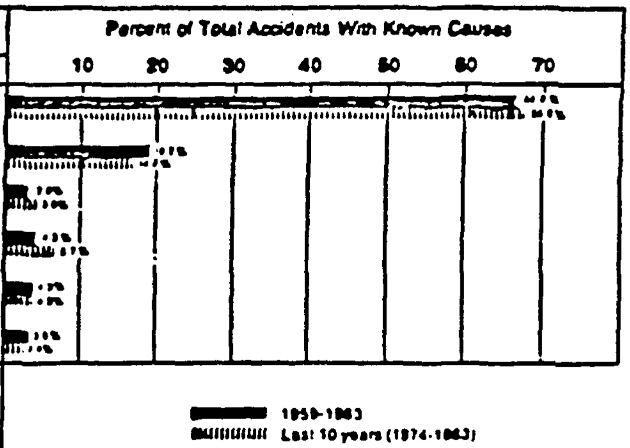
decreased, while accidents due to frailties and inadequacies of crew members have remained stable (see Figure 1). Additionally, efforts to reduce human error through automation have had little impact on the rate of errors committed. As aircraft systems become more complex and automated, opportunity for new error emerges. Thus, in spite of technological efforts to reduce pilot error, these rates remain stable.

This troubling aspect of contemporary aviation has spurred interest in establishing procedures to reduce the human error component in aviation.

Recent research efforts to address the pilot error problem have been directed towards improving cockpit designs, improving cockpit crew coordination, improving accident investigation and reporting techniques, and improving crew training. This includes the numerous programs conducted by research laboratories of the Army, Navy, and Air Force, NASA, the FAA, the National Transportation Safety Board, the major air framers, and many domestic and foreign air carriers, along with the universities that focus on aviation research. However, studies which investigate the occurrence of individual, as opposed to crew, cockpit error and the individual differences that may influence this error behavior have been deficient. An understanding of the type and

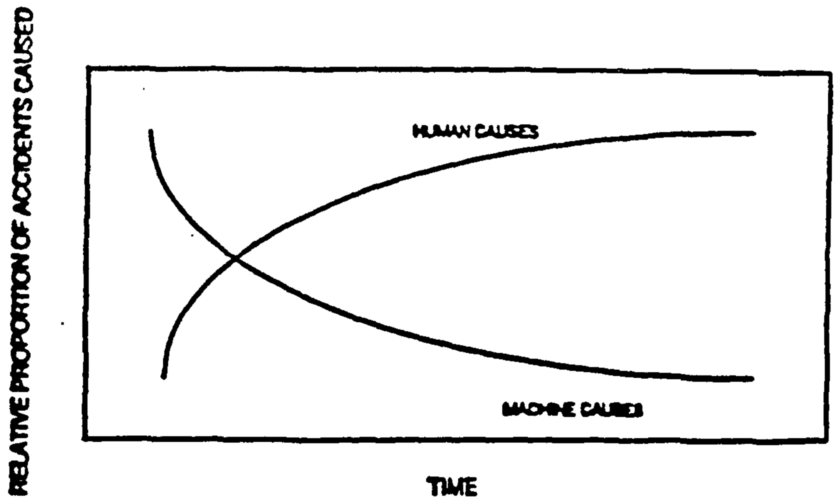
Figure 1

Probable Cause	No. of Accidents: Total	No. of Accidents: Last 10 yrs
Cockpit Crew	405	174
Airplane	110	36
Maintenance	17	9
Weather	26	17
Airport/ATC	26	11
Misc (Other)	21	6
Total With Known Causes	605	253
Unknown or Awaiting Reports	83	24
Total	688	277



Causal factors for air carrier accidents, 1959–1983: worldwide jet fleet, all operations. (Excludes sabotage, military actions, turbulence and evacuation injury.) "Airplane" includes airframe, aircraft systems, and powerplant.

(Nagel, 1988)



Trends in the causality of accidents. As aircraft and systems have become more reliable over time, the relative proportion of accidents attributed to human error has systematically increased. (International Civil Aviation Organization, 1984.) (Nagel, 1988)

frequency of individual cockpit error will aid understanding the eventual outcomes associated with it. An understanding of the factors or individual differences underlying cockpit error will contribute to the advancement of methods to reduce this dangerous aspect of pilot performance.

Aviation psychology has, in the past, regularly concentrated on analysis of accident data and post hoc suppositions regarding pilot error caused disasters. Rather than adopt such a retrospective view of pilot error, this present research assessed pilot error in the cockpit with the assumption that this error may lead to future aircraft accidents. This assumption is founded on recent writings concerning human error.

Reason and Mycielska (1982), in discussing catastrophic accidents, state: "Quite often, the contributing errors are relatively trifling things that in more forgiving circumstances would pass without significance. Accidents are errors with sad consequences" (p. 3). Further, Reason and Mycielska claim that the difference between insignificant consequences and tragic accidents does not lie in the nature of the error but rather the extent to which the circumstances surrounding the error "penalize it" (p. 3). Thus, they suggest that studying what might be viewed as irrelevant human error

can reveal important aspects of the systematic determinants which underlie it. Knowing the systematic determinants may guide the development of methods aimed at reducing the occurrence of these errors. Consideration of these suggestions was influential in designing this current research project to evaluate cockpit error. The errors which this study assessed may or may not lead to catastrophic consequences depending on the circumstances surrounding the error. However, the possibility that such errors could result in tragedy justifies this research approach.

A simple recording of cockpit error behavior and a discussion regarding the universal psychological mechanisms associated with it would yield a representation of pilot functioning in the cockpit, but such an analysis would lack a perspective of the factors that may predispose an individual to committing such error. Efforts to reduce pilot error should attempt to understand the elements that contribute to its occurrence. The aim of this research project was to achieve an accurate assessment of the type and frequency of cockpit error and to attempt to identify underlying individual dimensions or characteristics that may influence it.

RESEARCH FOCUS

The focus of this dissertation was an investigation of pilot cockpit error, specifically perception and judgement activities, and the relationship of personal characteristics that may influence the occurrence of this error. Underlying this focus was the general hypothesis: Personality dimensions, individual attitudes, and cognitive ability influence the type and frequency of pilot error.

Within this general hypothesis several potential relationships were studied. The relationship of specific personality dimensions, cognitive ability, and attitude variables to pilot error was examined. Additionally, it had been expected that particular combinations of these variables may have a greater influence on pilot error behavior than any of these variables in isolation. Several aviation researchers have recently suggested that a personality/attitudinal profile that considers several characteristics together might be related more closely to performance than would any single characteristic alone (Intano & Lofaro, 1989; Helmreich, 1982; Dolgin & Gibb,

1988; Siem, 1988: Chidester, 1987; Retzlaff & Gilbertini, 1987; Fry & Reinhardt, 1969; Novello & Youssef, 1974).

The possibility that the relationship between individual difference variables and pilot error is mediated by additional variables was also studied. A common assumption among aviation researchers (for example, Adams and Thompson, 1987) is that the relationship between underlying factors and pilot error is mediated by a third variable termed "situational awareness".

Although various definitions of situational awareness can be generated, most share the common theme that situational awareness is the accurate perception of the factors and conditions affecting the aircraft and the flight crew. This is an especially important issue in the area of safety, since several airline crashes have been attributed to the failure of crews and individual pilots to maintain adequate situational awareness as they sought solutions to relatively minor problems. The assumption that pilot error is influenced by an accurate perception of the environment is intuitively appealing, but this association had not been empirically tested (a review of the concept is included in the literature review that follows). This dissertation research attempted to determine if individual characteristics do influence

situational awareness and if a pilot's situational awareness is related to pilot error.

Another widespread assumption of aviation psychology, generated from FAA aircraft accident analysis (Jensen & Benel, 1977) is that specific, individual cognitive styles impact pilot error. Based on these post hoc accident analyses, the FAA, along with other aviation communities such as the United States Army Safety Center, claims that pilot "hazardous thought patterns" are important contributors to pilot error caused accidents. However, empirical research addressing this assumption is scant (a complete review of the concept is included in the literature review that follows). Pilot hazardous thought patterns were assessed in this present research, and the relationship to error behavior was investigated.

In summary, this research attempted to isolate personality, attitude, and cognitive factors that may influence pilot cockpit error. The mediating influence of situational awareness, psychological stress level, and pilot hazardous thought styles was also investigated.

This research was based on several lines of converging literature. The recent literature in the area of individual differences and performance is the foundation for this attempt to isolate personality, attitude, and cognitive variables that affect error

behavior. Pilot error is a critical component of pilot performance. Within the literature addressing individual differences and performance, this dissertation focused on the research concerning individual differences and cockpit behavior and individual differences as predictors of aircraft accident involvement. Only a brief summary of the general literature of individual differences and performance is presented, as that body of studies is so vast that it was not within the scope of this project to present a comprehensive review (for such a review see Edens, 1988).

LITERATURE REVIEW

A brief synopsis of personality assessment and performance is presented first to give the reader an overall sense of the issues that have influenced this area of applied research.

This review then focuses on the recent literature addressing individual differences and pilot and crew performance and individual differences and pilot accident involvement. The general hypothesis generating this present research and the selection of assessment instruments used were based on this body of literature.

The review briefly discusses the concepts of situational awareness and hazardous thought patterns. This is offered as supporting documentation for the inclusion of these variables in the model of pilot error.

A summary of human decision making biases and constraints is presented because of the relevancy to cognitive based, as opposed to psychomotor, error.

A brief historical review of the accident proneness literature is also presented. This literature contains the justification for including the personality dimension of social maladjustment in the model of pilot error, as

well as the specific assessment scale that this present research employed.

An overview of the prior research addressing the effects of psychological stress on pilot performance is presented, as the present research evaluates psychological stress levels and their association to pilot error.

Personality and Performance

Among the many hypothesized elements contributing to performance, personality has often been viewed as a potentially important variable. Personality characteristics are by definition stable traits that influence behavior. Job performance is one aspect of behavior of specific interest to Industrial Organizational psychology. However, the relationship between personality characteristics and successful or unsuccessful performance has not been easily demonstrated in the past. Guion and Gottier (1965) presented an extensive review of organizational personality research related to selection and subsequent job success from the years 1952 through 1963. This review concentrated on published articles from The Journal of Applied Psychology and Personnel Psychology. Guion and Gottier caution that each test reviewed was considered as an individual predictor, and the various contributions of a particular test to multiple

variable prediction had not been evaluated. Additionally, the authors note that these studies employed concurrent validity designs, rather than predictive validity designs. With these constraints noted, Guion and Gottier concluded that, congruent with the trend in personality research in general, research employing personality assessment in organizations had yielded largely non-significant results. Overall results above .30 were seldom attained. This review fostered a pessimistic view of personality assessment in organizations that has only recently begun to be reevaluated.

Results of contemporary research in organizational settings and current reviews of the existing literature are not in absolute agreement with Guion and Gottier's findings. This more recent work shows improved methodology and improved statistical techniques are resulting in respectable predictive validity in personality-performance associations (Bentz, 1985).

It is not within the scope of this paper to cite each study or each review regarding the general issue of personality and performance (for this comprehensive review see Edens, 1988). However, it is appropriate to point out that meta-analytic techniques, developed since the early damaging reviews were written, when properly applied show that the previous reviews may have been inaccurate due to

statistical artifacts. When these artifacts are properly corrected, the relationship between personality characteristics and performance becomes more consistent.

These recent reviews have revived, mildly, the scientific interest in personality assessment in organizations. Bernardin and Bownas (1985) state: "Despite the lack of attention to this research area in the academic journals and texts, virtually every organization with which we are familiar makes personnel decisions on the basis of some type of personality assessment. Trait-based performance appraisal systems, selection interviews, and the like reflect some underlying form of informal personality assessment" (p. v). They claim that "the true issue becomes not whether personality variables will be assessed in organizations but which characteristics should be measured and how they can be assessed most validly" (p. v).

Since the present study focused on personality and performance in aviation settings, the historical research findings from that body of literature were considered. The previously cited research demonstrates that methodological inadequacies lead to unsuccessful results. Although reliable links between personality and pilot performance had not been consistently demonstrated in previous research, Chidester and Foushee (1989) suggest

that this may be due to several factors tangential to the true issue of personality and pilot performance. This theme has reappeared in critical reviews discussing personality assessment in aviation from its inception to the present and thus is deserving of detailed mention here.

World War II was the most significant event in the history of pilot selection. It became urgent to define valid systems for classifying individuals into jobs consistent with abilities and emotional stability. The context of war necessitated the elimination of pilot candidates with pathological disorders, but time constraints did not permit the luxury of investigation of characteristics that influenced pilot success. These efforts to rule out psychopathology in the pilot population employed clinical assessment instruments. Research following the war continued to use these clinical instruments in efforts to establish personality-performance links. Ellis and Conrad (1948, cited in Chidester & Foushee, 1989) point out that the scales employed initially to identify candidates with psychological disorders were subsequently applied to pass-fail criteria without a theoretical basis.

One difficulty was that the original validation of the personality inventories was in terms of psychological

criteria and not in terms of performance criteria. Ensuing research efforts, attempting to predict pilot performance, were severely flawed by using, essentially, improperly validated assessment instruments. This limitation, coupled with another methodological difficulty, the criterion of training success or failure, severely confined the outcomes of these studies. The criterion, training success or failure, is often either inappropriate or contaminated or both. For example, very little variance occurs in training grades of military student pilots in present training programs. Dolgin, Gibb, Nontasak, and Helm (1987) and Shannon and Waag (1972) claim that this restricted range in grading flight performance is a major reason for the unfavorable results. They add that rating biases (halo), test response biases, and homogeneity of the sample contribute to non-significant results.

Thus, using improperly validated instruments atheoretically with unreliable or inappropriate criteria resulted in largely negative conclusions regarding the personality-performance link.

Realizing the failings of this methodology, efforts to develop and apply less clinically oriented and more construct valid assessment tools were initiated. However, these modifications did not completely resolve the

problems intrinsic to the previous research. Although the move away from the clinical assessment instruments was a methodological improvement, the use of training success or failure remained a troublesome criterion. Helmreich (1989) claims that personality's dismal record in predicting pilot performance is largely due to the choice of criteria against which personality constructs have been validated.

> If we examine the voluminous literature on pilot selection, we find that the criteria employed almost exclusively deal with initial training. The pilot performance criterion is usually defined as success or failure in completing initial training or rated performance in training. Performance in training is only a valid criterion if it correlates strongly with the desired outcome . . . performance in line operations. There is, in fact, little or no evidence to support the view that performance in training is a strong predictor of subsequent line performance. (p. 1)

Recently, Dolgin and Gibb (1987; 1988) summarized the methodological problems encountered in attempting to predict training performance using personality assessment:

> Most efforts to increase the predictive validity of aviation screening systems have some inherent methodological problems. Typically, test measurement variables are related to global criterion performance measures in training such as graduation/elimination or composite flight grades. Such performance criteria, although highly useful, have several undesirable psychometric properties and may obscure the components of skilled performance or behavioral attributes associated with the selection test measure. Presumably, a given test measure may be highly predictive of a critical performance dimension during some phase or component of flight training, but the insensitivity or impracticality of the performance

> criterion may yield low correlations and a consequent dismissal of the test's predictive power" (p. 13)

Additionally, the authors note that the vast majority of investigations used subjects that already were preselected by standard selection measures, the inference being that this methodology also results in restricted range problems. Thus, restricted range occurs both in the predictor and in the criterion.

Helmreich, Sawin, and Carsrud (1986) further point out that different combinations of predictors relate to quite different measures of performance at different points in time. The authors found that personality variables did not predict performance shortly post training but did predict performance after several months on the job. They suggest that this effect may be due to strong motivation to succeed in a new job plus the effect of being in a new environment where the rules for acceptable performance are not yet clear. This strong motivation and uncertainty may mask important personality variables during the initial weeks on a job, and a performance-personality relationship will be obscured. However, with time and experience on the job, these personality variables will exert a stronger influence on performance. Helmreich, et al. term this phenomenon the "honeymoon effect" and suggest that this finding be

considered when investigating links between personality and job performance.

In summary, the reviews of the research on personality and pilot performance claim that this body of studies has been methodologically flawed: (1) the initial instruments used in this paradigm were clinically validated and then subsequently applied in attempts to predict performance rather than to describe psychopathology as originally intended, (2) range restriction occurs in predictors as well as criterion, and (3) the timing, in the job history, of the criterion collection may cloud the true picture (e.g., "honeymoon effect").

Attending to these concerns, the present research used (1) individual difference measures that have been previously validated with various accident behavior criteria; (2) criteria that subject matter experts indicated would be less troubled by the range restriction that characterizes pass/fail training grades; (3) assessment measures that had been previously employed as flight school selection devices were not used in the present study to predict future pilot performance, thus hopefully eliminating the restricted range problem in the predictors. The timing of the collection of the criterion (the training environment) could not be altered.

Recent research investigating criterion variables other than training success has contributed evidence which indicates that, when the methodological problems discussed above are addressed, personality should be considered as an important factor influencing pilot performance. The specific research will be presented next.

Pilot and Crew Performance

Over twenty years ago, Fry and Reinhardt (1969) found that jet pilots do in fact display personality profiles that they claim are dissimilar to those of the general population. Using the Edwards Personal Preference Schedule, Fry and Reinhardt found that Navy Jet pilots "express greater manifest needs on the areas of heterosexuality, dominance, change, achievement, and exhibition, while expressing lower manifest needs in the areas of nurturance, abasement, deference, order, and succorance." Novello and Youssef (1974) demonstrated that civil aviation pilots also express this personality profile. Fry and Reinhardt conclude: "It still remains to be demonstrated, however, that these differences have any practical usefulness within the aviation community." Since the Novello and Youssef study in 1974, there have been dynamic research efforts to uncover the relationships between individual differences and pilot performance. The

landmark research generated by Robert Helmreich at the University of Texas at Austin has had the most dramatic impact in the field which studies individual differences and pilot performance. Since the findings from this crew performance paradigm heavily influenced the general hypothesis of this present research project, and since the present research project adopted Cockpit Resource Management predictor measures, it is appropriate to present the historical antecedents of this group of studies, and a summary of the recent research.

Presently, in aviation psychology, the term "Cockpit Resource Management" surrounds the research interests of commercial air carriers, military aviation communities, government agencies, academic and applied psychologists concerned with flight crew performance. The concept of Cockpit Resource Management is the result of the well placed concern that began when analyses of major catastrophic airline accidents clearly attributed the cause of the disasters to inadequate crew performance. This is differentiated from individual pilot performance, but still labeled "pilot error."

During the mid and late 1970s, the National Transportation Safety Board and the FAA (1988) discovered that poor interpersonal communications among crew members or inadequate delegation of duties among crew members

affected the safety of airliners. Examples of mishaps can illustrate the type of problems representatives of the FAA and the NTSB were finding occurring in cockpits of commercial air carriers. It was the following accidents that led to the initiation of measures to address flight crew performance.

In the middle 1970s an Eastern Airlines L1011 was on approach to Miami International airport en route from New York. The weather was clear and the flight had been uneventful. The landing gear warning light came on unexpectedly, signaling the crew that the gear was not engaged. The autopilot was on at this time. Cockpit Voice Recorder (CVR) tapes showed that the entire flight crew became involved with trying to solve the landing gear light malfunction. None of the crew members noticed that the auto pilot had accidently become disengaged. The aircraft lost altitude rapidly and crashed in the everglades, killing several hundred persons.

Many other similar incidents with the same unfortunate consequences have occurred. In 1978 a United Airlines cargo liner crashed over Utah when the Captain ignored the flight engineer's warning of low fuel. The airplane ran out of fuel and crashed into a mountain. The famous Air Florida disaster of 1982, when the 737 landed on the 14th Street bridge in Washington, D.C. on take off

from National Airport, has been cited by the investigative boards for the total negligence of the crew in de-icing procedures, ignoring take-off engine readings that the first officer construed as faulty, and ignoring standard operating procedures for the Boeing 737 that they were flying.

The Eastern Airlines L1011 and the United Airlines air cargo disasters were the impetus for government agencies to encourage training efforts to improve flight deck resource management. These agencies strongly encouraged the airlines to address the "pilot error problem." Training was to include areas other than manual control and systems operations. Recently, the regulatory agencies have made this training mandatory.

FAA accident analyses found that mishaps which could be attributed to pilot error share some common factors, each of which is an element of what has become known as the "resource problem." Cockpit Resource Management training was designed, in effect, to reduce the incidence of these factors.

The common factors identified by the FAA and NTSB are:

1. Preoccupation with minor mechanical problems
2. Inadequate leadership
3. Failure to set priorities

4. Inadequate monitoring
5. Failure to delegate tasks and assign responsibilities
6. Failure to utilize available data
7. Failure to communicate intent and plans. (Lauber, 1979.)

Based on these findings, plans to address these problems were of central interest to aviation communities. The group of researchers (Helmreich, Spence, Chidester, Foushee, Wilhelm, Gregorich) that initiated, and are still most prominent in, Cockpit Resource Management are under the direction of Robert Helmreich. The body of literature which addresses crew interactions or resource management on the flight deck has mostly been generated by the thoughts of these individuals. The assessment battery used in crew performance studies was developed by these researchers, as well.

Microscopic analysis of accidents attributed to pilot error suggests that a high proportion of these incidents were results of failures to effectively manage the human resources available (Helmreich, 1982).

> It does not require a large leap of faith to posit that the PERSONALITIES of crew members should be related to their style of management, and our approach to crew coordination has taken two parallel paths--exploration of personality factors associated with flight crew performance and work on training in resource management." (Helmreich, 1982, p. 3)

In order to investigate this hypothesis Helmreich et al. developed, tested, and validated a battery of personality and attitude measures appropriate to aviation settings. The current research project focused on the personality and attitudinal characteristics of individuals that may influence cockpit error. The self report inventories developed by Helmreich and Spence and used by researchers investigating crew performance are of specific interest to the current project. Helmreich and his colleagues use the battery to predict crew performance, and the battery has successfully predicted individual pilot performance in the past (for example, Intanto & Lofaro (in preparation); Chidester, 1986; Foushee, 1984). The measures are designed to reflect characteristics of the cockpit environment and are thus more specific than the original generic measures from which some were adopted. Guion and Gottier (1965) have suggested that, when considering personality assessment as predictor measures, the use of scales that have been developed for a specific population or setting may have better predictive validity than more general measures. The above evidence influenced the choice of these instruments for the present study of individual differences and pilot error. The Helmreich battery is one of three individual difference measures employed in this study.

The battery consists of four scales. Many studies (for example Chidester, 1986; Chidester & Foushee, 1988) which focus on crew performance have employed the Extended Personal Attributes Questionnaire (EPAQ: Spence & Helmreich, 1978), the Work and Family Orientation Questionnaire (WOFO: Helmreich & Spence, 1978) the Cockpit Management Attitudes Questionnaire (1984), and the Revised Jenkins Activity Survey (Helmreich, Spence, & Pred, submitted for publication and cited in Helmreich, in press). This battery was developed based on findings from research (Helmreich, 1982) which indicated that personality traits clustering in the areas of achievement motivation and interpersonal sensitivity are strongly related to measures of crew performance. Helmreich (1982) terms these two core dimensions: INSTRUMENTALITY and EXPRESSIVITY. Instrumentality refers to traits of achievement seeking and goal seeking, including aspects of achievement motivation. Expressivity refers to traits of interpersonal behaviors and interpersonal orientation.

The EPAQ (Extended Personal Attributes Questionnaire) is a general measure of positive and negative constellations of instrumental and expressive traits. The WOFO (Work Orientation and Family Orientation) is a more specific measure of instrumentality, reflecting achievement motivation. It operationalizes achievement

motivation as three distinct but correlated components defined as: Mastery Needs (the desire to undertake new and demanding tasks); Work Orientation (which assesses satisfaction with hard work and task completion), and Competitiveness (which assesses the concern with outperforming others in interpersonal situations.)

Helmreich studies indicate that the EPAQ and the WOFO have demonstrated substantial validity (Helmreich, 1982; Helmreich & Wilhelm, 1988; 1989; Chidester, 1986, cited in Helmreich, in press). Scores from the EPAQ have been associated with a variety of criteria of adjustment and accomplishment. The three scales of the WOFO have shown a consistent pattern of correlations with various performance measures. Data that relate these measures to flying performance have shown consistent, significant relationships. Helmreich claims that results of this research indicate that the positive attributes, Instrumentality and its related components, Mastery and Work, as well as Expressivity are positive predictors of performance. Competitiveness, consistent with research in other settings (not referenced in this article) proves to be a negative correlate of performance as does high verbal aggressiveness. In discussing the EPAQ, Helmreich (1982) states:

> The instrument has proved to have high predictive validity in a variety of settings ranging from scientific attainment to income, and job, life, and marital satisfaction. One of the interesting outcomes of research with the instrument has been the discovery that, although several of the scales are positively correlated, in many cases the predictors interact with regard to performance criteria. To cite one example, in past measures of achievement motivation, components were summed to form a unitary measure of the need to achieve. They [the components] included a need to succeed in new challenges, motivation to work hard and satisfaction with work, and interpersonal competitiveness--the desire to beat others. Somewhat to our surprise, we have found that, although work and mastery are predictably, positively related to performance, in many settings including scientific attainment and business, competitiveness is a negative predictor. In previous work, these factors having been lumped together may have canceled out, leading to poor prediction. Our approach has been multivariate, examining the single and multiple relations of predictors with each type of performance criteria. (p. 4)

In addition to these measures, Helmreich developed The Cockpit Management Attitude questionnaire (Helmreich, 1984). This 25-item questionnaire has a set of performance validated items, and three empirically derived subscales. These subscales, leadership, group atmosphere, and personal invulnerability, sample the major topic areas of cockpit resource management (Chidester, 1987)

Helmreich draws a distinction between personality traits and attitudes, stressing the stability of personality and the malleability of attitudes. Findings regarding each of these dimensions have unique implications for applied settings. Basically, selection

procedures should address personality issues, and training may be able to address attitudinal issues. Thus, research in aviation tends to assess both dimensions of the individual.

Most current research in this paradigm, which focuses on pilot performance, also includes a measure of what has become known as Type A behavior. The traditional measure of Type A personality is the Jenkins activity scale. Pred, Helmreich, and Spence (cited in Helmreich, 1988) revised this scale and claim that this reformulation of the construct yields two factors that they label Achievement Striving (AS) and Impatience/Irritability (IS). Pred, Helmreich and Spence do not state the rationale behind the reformulation of the original Jenkins activity scale nor give the reasons that they found the original scale inappropriate for their research.

In summary, the Helmreich Battery consists of the Extended Personal Attributes Questionnaire; the Work and Family Orientation Questionnaire; the Cockpit Management Attitudes Questionnaire; and The Revised Jenkins Activity Survey. The current research project used the entire battery in student pilot assessment, along with the Eysenck Personality Inventory and the Social Maladjustment Scale, discussed and described later in this paper. Current research based on the theoretical assumptions of

this paradigm and employing the Helmreich battery is presented next.

As suggested by Helmreich, Chidester (1986; cited in Helmreich, 1988) found that instrumental and expressive attributes were related to both technical and managerial aspects of flight crew performance. Achievement Striving was a positive predictor of performance, and Impatience/ Irritability was associated with health complaints among flight crew members.

Also, Chidester (1987) demonstrated that, although all pilots benefitted from CRM training, those pilots scoring higher on instrumental and interpersonal characteristics benefitted the most. Chidester explains that leadership attitudes were not affected by training, but pilots with the high scores on instrumental and interpersonal characteristics had more positive leadership attitudes both before and after training than the other pilot groups. Also, group atmosphere attitudes were enhanced by training only among Positive Instrumental/Interpersonal pilots. Recognition of personal vulnerability to stress, personal problems, and the skills of fellow crew members was enhanced by training among all pilot subjects.

Gregorich, Helmreich, Wilhelm and Chidester (1989) showed that particular subgroups of pilots could be identified according to personality characteristics and

that the particular subgroups of pilots differed on performance measures. This study found pilots that are above average in achievement motivation, work motivation, and possessing a strong tendency towards interpersonal warmth, combined with low levels of verbal aggression, out performed other pilot subgroups in performance checkrides. Less successful pilots were characterized by high levels of achievement motivation, but also high levels of autocratic, dictatorial orientation combined with high levels of verbal aggression. The least successful pilots were characterized by low levels of achievement motivation, interpersonal orientation, and competitiveness.

Subsequently, Chidester (1988) employing an algorithm derived from the previous study, was able to classify pilots into one of the three personality profiles, and demonstrated differential error rates for crews led by captains with dissimilar profiles. This study was unique in that it evaluated crew error as well as overall effectiveness of the captain. Crew performance data was collected from three sources: expert observations, video-coding of crew errors, and computer recording of aircraft handling parameters. A three level error classification was utilized. Errors were defined as: minor, with a low probability of serious flight safety consequences;

moderate, with a stronger potential for flight safety; and major operationally significant errors having a direct negative impact upon flight safety.

Results indicated that minor errors were randomly distributed across crews; crews tended to make more moderate than major errors. Crews led by below average achievement motivation and negative expressive style captains tended to make more errors than those led by high achievement motivation and high interpersonal orientation captains or crews led by a captain with high levels of competitiveness, verbal aggressiveness, and impatience and irritability. This study considered only the personality of the captain of each crew evaluated.

Implementing the predictor measures developed by the Cockpit Resource Management researchers and used in the above studies, Intano and Lofaro (1989) were also able to identify the same three subgroups in their helicopter pilot population. Recent analysis of incoming data has shown that these clusters of personality dimensions are related to academic and flight performance during training (Intano, 1990, personal communication).

Because of the conclusions from the research summarized above and because of its widespread acceptance in aviation psychology applied research, the Helmreich battery was used in the current research project to assess

personality characteristics and attitude differences as predictors of pilot cockpit error in the student helicopter population.

This literature review now shifts from the presentation on research focusing on crew performance employing Helmreich methodology and based on crew resource management, to two other current studies that have centered on individual differences and pilot performance.

An investigation focusing on the relationship of individual differences and accident involvement revealed that pilots could be classified as accident involved or accident free according to personality variables. Saunders and Hoffman (1975) demonstrated that three of the factors on the 16PF (Group Dependent or Self-Sufficient, Practical vs. Imaginative, and Forthright vs. Shrewd) discriminated between those individuals who had been identified as the causal factor in the particular accident, and those individuals who had not been the cause of an accident. This study was able to classify 86% of the aviators as to their prior pilot error accident involvement.

An attempt to cross validate these results failed (Saunders & Hoffman, 1976). The cross validation data did not exhibit the differences between the accident involved and the accident free groups. The authors state:

> Of course, one could not expect to account for all pilot-error involvement with personality variables because of the obvious importance of environmental, equipment design, training, and situational factors. However, since the ultimate responsibility for safe flight resides with the pilot, one cannot underestimate the influence of personal characteristics upon flight performance nor completely abandon the goal of developing measures of them which can be related to performance. Toward this end, potentially productive areas of research concerning the pilot error problem might be: (1) examination of individual differences in perception of hazard, and (2) a detailed investigation of errors frequently occurring in clusters. (p. 179)

The present research addressed the suggestions of Saunders and Hoffman. Perception of hazard was measured by measuring the more general perception of the flight environment or situational awareness. The present research evaluated type and frequency of pilot error.

Situational Awareness

Pilot situational awareness can be conceptualized as an accurate perception of the factors and conditions that affect the aircraft and flight crew. This individual view of reality is the result of a chain of information processing events that consists of sensing and decoding of environmental data, classification and attaching meaning to the data, making decisions and judgments based on the data, implementation of decisions, and monitoring feedback (Gerbert & Klemmer, 1986).

The resulting perceptions from this information processing chain of events are influenced by many elements related to the individual. For example, Bolman (1980) claims that one's view of reality is based on individual goals, beliefs, and behaviors. Reason (1987) claims that universal cognitive mechanisms influence the accuracy of these perceptions.

Bolman (1980), in discussing situational awareness, suggests that because individuals can never have exact knowledge of the "true situation" of their environment they must develop a "theory of the situation." This theory of the situation is derived from knowledge structures particular to the individual. These knowledge structures are based on goals, beliefs, and behaviors that have been developed over the course of the life of the individual. The knowledge structures guide and direct behavior and decision making. The knowledge structures provide a coherent picture of what the individual perceives as happening. Decisions as to what or which action is appropriate to this perceived theory are therefore based largely on past experience. This aspect of environmental assessment leaves the individual vulnerable to error, especially in complex and unfamiliar situations.

When presented with a simple or familiar situation, the theory of the situation and reality can be, or actually are, highly concordant. Essentially, the individual applies past experience to the similar situation and arrives at a conclusion about the state of the environment. However, when the situation becomes complex or novel, the chances of error in the assessment of the situation become much higher, as the individual has little stored experience to rely on.

Adding to the possibility of inaccurate situational awareness is the fact, Bolman claims, that individuals are not inclined to revise a theory that is already developed. To do so requires time, energy, effort, and often emotional stress. Similarly, Reason (1987) claims that humans seek ways to minimize cognitive strain. Thus, if Bolman and Reason are correct, individuals will maintain a view of reality that is comfortably familiar rather than attempt to construct a new or cognitively foreign view which may be a more accurate representation of the environment.

Reason (1988) also suggests that errors in the assessment of a situation occur as a result of highly organized knowledge bases which compose human cognition. "A knowledge base that contains specialized theories rather than isolated facts preserves meaningfulness, but

renders us liable to confirmation bias. An extraordinarily rapid retrieval system, capable of locating relevant items within a virtually unlimited knowledge base, causes our interpretations of the present and anticipations of the future to be shaped too much by the matching irregularities of the past" (p. 2).

Reason (1988a) argues with regard to cognitive failure:

> The more predictable varieties of human fallibility have their origins in useful and adaptive processes. In particular, they arise from a natural tendency to minimize 'cognitive strain' [see Bruner et al., 1956] and to over-utilize those stored-knowledge structures, heuristics, and short-cuts that allow us to simplify complex informational problems. (p. 47)

Reason states that:

> Human beings are compulsive pattern matchers. When confronted with new problems, their automatic reaction is to seek some 'off the shelf' solution from within their stock of stored routines. Such choices are markedly influenced by two simple heuristics: (a) match like with like; and (b) where there is a set of equally matched possibilities, apply the most used one. (p. 47)

Reason also presents a microscopic view of the antecedents of inaccurate situational awareness when discussing information processing biases. Reason (1987a) proposes that inherent cognitive organizational systems that are necessary for normal psychological functioning may sabotage the accuracy of the information processing chain of events. He argues that human error and

successful performance are two sides of the same coin. Components of normal psychological functioning which operate to organize cognitive information underlie human information processing errors. Reason claims that information processing is influenced by basic error tendencies. "These basic error tendencies are: ecological constraints, change-enhancing biases, resource limitations, schema properties, and the use of particular strategies or heuristics" (p. 6).

Ecological constraints, change enhancing biases, and resource limitations basically speak to the evolutionary, developmental, and physiological constraints of the human brain and nervous system. According to Reason, humans inherently do not have the capacity to sense, interpret, and integrate information from technologically complex environments with total accuracy.

Schema properties refers to the system by which humans store and represent past experiences. Reason (1987a) claims that humans tend to err on the side of familiarity.

> Systematic errors can arise (a) from fitting the data to the wrong schema; (b) from employing the correct schema too enthusiastically so that gaps in a stimulus configuration are filled with best guesses rather than available sensory data; and (c) from relying too heavily upon active or salient schemata. Such errors are likely to occur at times of change when existing routines are no longer appropriate for new circumstances of revised goals. (p. 8)

Strategies and heuristics refers to the processes that humans use in fitting new data into the already existing schemata.

In summary, Bolman and Reason propose that human fallibility in situational awareness has its origins in the organizational and adaptive processes of the cognitive system. Specifically, errors arise because of the physiological constraints of the human nervous system, the human tendency to minimize psychological distress associated with ambiguity and indecision, and the human tendency to minimize cognitive load and to over rely on past experience to interpret new or novel data.

Given that these parameters of human cognition exist, it seems reasonable to propose the possibility that the personality dimensions of impulsivity and achievement motivation may relate to the tendency towards rapid resolution of ambiguous environmental cues in situational theory building. Thus, this dissertation research investigated the conceivable links between the personality dimensions of impulsivity, motivation, and pilot cockpit error. Impulsivity could lead to careless error prone cockpit behavior, mediated by poor situational awareness. Additionally, because individuals differ in goal accomplishment motivation, it seems reasonable to suggest that individuals will also differ in the willingness to

endure goal associated psychological discomfort. If Bolman and Reason are correct, that individuals tend to minimize cognitive strain and that attaining an accurate perception of reality in complex environments produces cognitive strain, individual motivation may play a role in determining how much psychological discomfort an individual will tolerate in goal seeking. This research assessed individual motivation employing the Helmreich battery described earlier.

An individual's situational awareness may be influenced by other personality characteristics along with the cognitive constraints just discussed.

Extroversion/introversion has been suggested as a factor contributing to an individual's perception of the environment. Tyler (1965) defines extroversion as

> . . . the kind of outward orientation that makes a person highly aware of what is going on around him and causes him to direct his energy toward objects and people outside himself. Introversion is the opposite inward-turning tendency that makes a person sensitive to his own feelings and experiences and causes him to direct his efforts toward understanding them. (p. 167)

Adopting this definition, it was reasonable to explore the relationship between extroversion/introversion and situational awareness, and pilot error. It was hypothesized that the extroverted individual who, according to Tyler, is "highly aware of what is going on

around him" (accurate situational awareness) would commit fewer judgmental/decisional errors then the less aware introverted individual. Conversely, the introverted individual, according to this definition of the trait, should be less aware of the situation and therefore commit a greater number of judgmental (cognition)/decisional errors. The present research explored the links between extroversion and situational awareness and between situational awareness and pilot error.

Recent research has revealed that pilots, as a population, tend to be more introverted than extroverted (Sellards, Corbi, & Sellards, 1989). The authors state:

> The introverted style is one of making decisions somewhat independently of constraints from the situation, culture, people, or things around them. They are quiet, diligent at working alone, and socially reserved. Some possible weaknesses for an introvert are that they avoid others, are misunderstood by others, misunderstand the external, and dislike being interrupted. The introvert has possible strengths identified as being independent, diligent, careful of generalizations, and careful before acting. (p. 3)

This description implies that pilots with the tendency toward introversion may be reserved in making decisions and taking action, possibly preferring to continue to seek pertinent information longer that would the extraverted individual. This tendency should lead to careful judgement and decisions. Since the introverted

individual is characterized as being diligent, adequate performance on vigilance tasks could also be expected.

This conceptualization of introverted tendencies is at odds with the conceptualization of introverted tendencies set forth by Tyler, and introduced above. Tyler implies that the introverted individual would be expected to have a less accurate perception of the environment, which this research project hypothesized as leading to pilot error. Sellards, Corbi, and Sellards describe the introverted individual as tending towards careful behavior which might be expected to lead to fewer pilot errors. These conflicting projections could be resolved when pilot error is broken down into judgement/ decision errors and attention/perception errors, as was done in this research project. The less accurate perception of the environment by introverted individuals as suggested by Tyler may result in judgement/decision errors. But, the tendency towards diligence and careful behavior characteristic of the introverted individual, as suggested by Sellars, et al., could result in fewer attention/perception errors. Thus it may be that extroverts are better at assessing the total environment, resulting in an accurate situational awareness, and introverts are better at tasks requiring diligence. Accordingly, extroverts could be expected to make fewer

judgement/decision errors and introverts could be expected to make fewer attention/perception errors. The present research project investigated the relationship between extroversion/introversion and these two basic types of cockpit error.

Farmer (1984) points out that extroversion/introversion can be related to arousal or activation levels in the individual. Eysenck (1963; cited in Farmer, 1984) and Broadbendt (1963; cited in Farmer, 1984) postulates that extroverts are under aroused and therefore seek stimulation; introverts are over aroused and thus avoid stimulation.

> It follows that environmental stressors which increase arousal level should have differential effects on the performance of these individuals. Particularly, if the task has a high level of difficulty, the performance of introverts would be expected to show a marked decline, whereas the performance of extroverts might even improve. (p. 176)

This description suggests that, because flying consists of complex tasks performed in an atmosphere of environmental stressors, extroverts should be expected to outperform introverts. If it is assumed that pilot error is an integral component of unsuccessful pilot performance, it should be expected that introverted individuals would have the tendency toward more errors than extroverts. Farmer further explains that introverts exhibit superior performance on vigilance tasks, which are typified by a

high level of monotony. The unstimulating characteristic of vigilance tasks may be congruent with the needs of the introverted personality. This present research combines vigilance tasks in the intricate flight environment. According to Farmer's conceptualization of the extroverted/introverted dimension of personality, it should be expected that introverts would commit fewer vigilance errors than the extroverted subjects, but because of the complexity of the flight environment, this relationship may not hold true.

In summary, various and somewhat conflicting opinions of the behavioral outcomes of extroversion/introversion personality characteristics have been put forth in the literature. One source suggests that extroverts should commit less judgement/decision errors; another source suggests that introverts should commit fewer errors in general; and a third source suggests that introverted individuals will show performance decrements in the presence of environmental stressors, but that introverts should commit fewer vigilance errors.

Given these conflicting descriptions of extroverted and introverted behavior, this dissertation examined the relationship between extroversion/introversion and situational awareness and pilot error in an exploratory nature. If Tyler is accurate, it should be expected that

extroverts would commit fewer judgmental (cognitive)/ decision errors than introverts because of a better perception of the environment. If Sellards is accurate, introverts should make fewer vigilance, attention/ perception errors because of a careful nature. If Farmer is correct, extroverts should make fewer judgmental (cognitive)/decisional errors, because of the complexity of the task, and introverts should make fewer vigilance errors, because of the tendency to seek monotony.

The personality dimensions of extraversion and introversion have been investigated in various studies of accident causation. Shaw and Sichel (1971) found that a poor safety record in bus drivers was associated with high levels of both extraversion and neuroticism. Automobile accident data will be discussed in the section on accident proneness.

Decision Making

Closely aligned to pilot situational awareness is pilot decision making. This dissertation research evaluated both of these cognitive dimensions and the effects of individual differences on each. It was hypothesized that situational awareness mediates the relationship between individual differences and decisional errors. Accordingly, a brief discussion of some current

ideas of decision making is presented. Many similarities between human decision making activities and the acquisition of situational awareness are evident.

Mosier-O'Neill (1989), in addressing decision making, claims that these activities are influenced by the saliency of the informational cues, representativeness and availability heuristics, and confirmation bias. The author affirms that, although information is available from several sources at any point in time, attention is often drawn only to the most conspicuous cues, to the exclusion of less obvious but equally important cues. Further, when presented with a situation, humans will base their actions on prior experience with a similar situation, sometimes ignoring novel information or conditions. Humans also tend to seek out only information that confirms what is already thought to be true.

Mosier-O'Neill further maintains that, once a familiar situation is detected, premature closure may result in subsequent signals being ignored. Related to the concept of premature closure, Kruglanski (1986; cited in Clements et al., 1989) states that in the decisional chain of events there is a point in the information search when individuals cease the data gathering process. Kruglanski terms this phenomenon "decisional freezing." Clements and his colleagues suggest that this tendency to truncate the

decision process results from the psychological stress which accompanies indecision or ambiguity. Similarly, Adams and Thompson (1987) claim that making good pilot decisions is a process which involves TIMELY assessment of all relevant situational factors, a decision to act (or not to act), and a response. "A judgmental decision always involves a problem or choice, an unknown element, and usually a time constraint and stress" (p. 2). Kruglanski (1986) claims that the termination of the information search phase of the decision making process may be influenced by motivational and "psychological pressures" of the decision maker. Further, he states that the need for a positive conclusion, the need for cognitive structure, and the fear of invalidity may distort the flow of information, leading to inaccurate decisions and, for a pilot, possibly tragedy.

There is a close parallel between these characterizations of human decision making and Bolman's and Reason's theories regarding human situational assessment leading to awareness discussed earlier in this paper: basically, that humans do not efficiently utilize all the available environmental information when engaged in decision making and closely associated situational assessment. It is suggested that inaccuracies occur partially due to universal inadequacies of the human

cognitive system and partially due to characteristics unique to the individual.

Intuitively it seems that faulty situational awareness contributes to decisional errors because faulty situational awareness provides inaccurate environmental cues to the decision maker, further complicating judgement and subsequent decisions. The relationship between situational awareness during flight and cockpit decisional errors was investigated in this research project.

It is moderate to propose that individual differences in the need for a positive conclusion and in the degree of fear of invalidity may exist while the need for cognitive structure may be a universal component of human information processing (Reason, 1988a). The need for positive conclusion may be guided by individual motivational forces, and/or impulsive tendencies.
The relationships between individual motivation, impulsivity, and pilot cockpit error were be examined in this present research project. Judgmental and decisional errors were evaluated, as well as attention and perception (vigilance) errors. It seems reasonable to suggest that an individual with impulsive tendencies may be prone to rapid information processing and solution, possibly not considering all the relevant data available. Along with

decisional error, it has been suggested that impulsivity may be linked to vigilance errors.

Gerbert and Kemmler (1986) define vigilance errors as "missing or fragmentary uptake of objectively present information" (p. 1444). Several researchers (Gerbert & Kemmler, 1986; Adams & Thompson, 1987) theorize that carelessness may be one factor responsible for vigilance errors. This is suggesting that carelessness may be a behavioral product of impulsive tendencies. Thus, in addition to investigating the impulsivity-decisional error link, this dissertation research also investigated the possible association between impulsivity and vigilance/attention/perception errors. Perhaps more impulsive individuals are less accurate than less impulsive individuals in assessing objective information because of the time required.

In summary, although humans have inherent cognitive processing constraints that affect decisional activities, individual personality characteristics may also play a part in decisional and vigilance behavior. This research project investigated these potential links of individual differences to cockpit error.

Hazardous Thought Patterns

Jensen and Benel (1977) reviewed general aviation accident data and concluded that faulty decision making by the pilot was responsible for 87% of mishaps. Because the incidence of faulty decisional activities is so pervasive and so costly, the FAA sought to identify the specific thought patterns that serve as the antecedents to irrational pilot judgement. In a collaborative effort, the FAA and researchers at the Embry Riddle Aeronautical University isolated, post hoc, five hazardous thought patterns which hypothetically are responsible for pilot error induced accidents. They labeled the thought patterns: anti-authority, impulsivity, invulnerability, macho, and external control. Aviation psychologists tend to view these cognitive styles as stable individual response dispositions which are thought to mediate the relationship between information processing and pilot judgement.

In two studies based on the Embry Riddle findings, Lester and Bombasi (1984) and Lester and Connoly (1987) were able to demonstrate that three of these hazardous thought patterns actually existed in approximately eighty percent of their pilot population. The invulnerability thought pattern was found to be the most common, followed by impulsivity patterns and then by macho tendencies. In

summary, the authors concluded that the three patterns of impulsivity, invulnerability, and macho may appropriately describe the major cognitive antecedents of irrational pilot judgement.

These findings provided reasonable justification for attempting new research that could possibly expand the understanding of the effects of personality and cognitive styles on pilot error. Thus, this present research project assessed the existence of hazardous thought patterns in the student pilot sample and examined the relationship between personality dimensions and these cognitive styles and the impact these cognitive styles have on cockpit error. Research assessing the impact of hazardous thought patterns on pilot error behavior has not been attempted. A relationship between personality, cognitive style, and accident behavior has only been hypothesized to exist. This dissertation assessed hazardous thought patterns in the pilot sample, attempted to identify underlying personality characteristics, and investigated the links between the cognitive styles and pilot error.

Accident Proneness

It was not the goal of the present project to analyze any accident data. However, because this project focused

on error behavior assuming it to be a potential precursor to accidents (Reason & Michelska, 1982) and personality variables that have been associated with accident involvement in prior studies, it is appropriate to present a brief summary of the concept of accident proneness.

The relationship between individual differences and accident susceptibility has been investigated many times and in many areas of human performance. However, the concept of accident proneness has been a controversial topic since its inception. Historically, the notion of individual differences in accident vulnerability has met with both enthusiasm and criticism. The concept has been awarded popularity and acclaim, as well as been severely questioned and rejected. Recently there has been renewed interest in uncovering personal characteristics that may be related to accident behavior. Several relatively current studies report promising findings that provide reason to reevaluate the skepticism surrounding individual differences, or more specifically personality characteristics and accident behavior (Saunders, 1975; Hansen, 1988; Hansen, 1989).

The idea that accidents may be influenced by individual characteristics originated with the work of Greenwood and Woods (1919, cited in McKenna, 1983) in what has become the most often cited research considering

accident proneness. Greenwood and Woods argued for the existence of accident prone individuals primarily by taking samples of workers and correlating accident rates between two successive time periods. Accident data gathered from different factories consistently showed that in a given period of time most workers experienced no accidents, while a small number experienced one or more. Greenwood and Woods proposed that, if accident proneness is a viable concept, then accident behavior should show reliability. The correlation coefficient between accidents in two or more time periods should be significant. McKenna (1983) states:

> Thus the correlation coefficient between the two periods has been used as a test of accident proneness. Those who doubt the accident proneness concept have pointed to the generally low correlations, and those who accept the accident proneness concept point to the generally significant correlation coefficients. (p. 66)

Criticisms of this approach included the idea that individuals may have differential exposure to risk, and simply evaluating accident occurrences in several time periods ignores this confound. McKenna points out that, while differential exposure to risk may render the interpretation of a significant correlation ambiguous, a nonsignificant correlation is strong evidence against the relationship between individual characteristics and accident involvement. Most recent studies recognize the

influence of exposure and consider this in research designs.

Hundreds of studies have been conducted on the association of personality and accidents. Most of the studies centered on automobile drivers and accidents. Hansen (1988) reviewed this vast literature and found wide variability in the quality and rigor of the research efforts. Further, Hansen claims that analysis of this literature employing the common criteria of the accident proneness concept would conclude that the concept is largely discredited. Part of the problem rests in what Hansen terms the common thoughts that have guided individual differences and accident involvement studies. Hansen suggests that reconceptualization of the these common thoughts could result in a better understanding of the role individual characteristics play in accidents.

Hansen claims that the long standing debate surrounding accident proneness may be, in part, the result of an inexact definition of the concept. While there is no agreed upon definition of accident proneness, most versions share common thoughts which have directed investigative efforts. Hansen suggests that it may be these common thoughts or assumptions, underlying this research paradigm, that are responsible for its inability to gain widespread acceptance.

The common thoughts are:

"1. Accident proneness is personality trait or syndrome. Most proponents regard it as a unitary trait.

2. Accident proneness is innate or inherent.

3. Accident proneness trait will 'cause' workers to be involved in accidents.

4. Accident proneness is stable across time.

5. Workers with the accident proneness trait will be involved in repeated accidents." (Hansen, 1988, p. 347).

Based on these assumptions, many "accident proneness" research reviews and psychology texts discussing the concept reach concordant conclusions. As examples, Tiffin and McCormick (1942) state: "At the present time, however, there probably is insufficient evidence to be able to support the notion of a generalized accident tendency" (p. 567). Szasz (1984) more recently states:

> We have indeed come far from the original notion that accidents are an 'affair of personality.' The textbooks and commentaries of the late 1950s and 1960s assign a very minor role to personality: 'Inherent accident proneness scarcely exists.' The majority of industrial psychologists and <u>all</u> industrial engineers reject the concept outright. (p. 32)

Hansen claims that conclusions such as these are reached when the accident/personality literature is evaluated employing the accident proneness paradigm, with

the common thoughts described above. Hansen's review of the literature on personality and automobile accidents found several of the common thoughts unsupported. This conclusion is only similar to the conclusions of the other reviewers (cited above) that clearly disregard personality/accident involvement relationships.

Hansen suggests that, however inconsistent the prior research has been, the findings from the studies that he reviewed revealed a number of personality traits, many unrelated to each other, that were associated with accidents. This fact does not support accident proneness as a unitary trait, as the common thoughts of the traditional view would emphasize. However, it does leave open the long standing question of exactly what influence personal characteristics have in accident vulnerability. Thus, in spite of a skeptical view of the past research methodology, Hansen does not disregard the hypothesis linking individual differences and accident involvement. It may be that a specific personality trait "accident proneness" does not exist, nor does any syndrome of closely related traits, as suggested in the common thoughts. But that does not exclude the possibility that personality variables have an impact on accident behavior, as this dissertation research hypothesized.

Addressing the common thought regarding the innateness or inherent nature of accident proneness, Hansen points out that this thought does not allow for people to change over time. This common thought of the accident proneness paradigm, for example, would not allow an impulsive adolescent to gain maturity over the years and become less impulsive and possibly less accident involved. Reviews of the literature find age associated with accident involvement in industrial workers as well as automobile drivers (e.g., Clements, Neggers, Melvin, Peck, Runcie, & Scott, 1989). This fact provides additional evidence that the traditional concept of accident proneness may be inaccurate but that the relationships between person-centered variables and accident behavior is worth investigating.

From the review, Hansen notes that neurotic and social maladjustment behavioral characteristics were significantly related to accident behavior in past research. On the subject of individual change and subsequent accident involvement rate change, Hansen points out that neurotic, anxious behavior is more likely to change with time than are more stable behavior such as that associated with social maladjustment. Thus, individual characteristics that are amenable to change or improvement can therefore be thought of as unstable. This

instability within the individual may result in varying accident rates. This may be a partial explanation for poor reliability of accident involvement. Psychologists (e.g., Helmreich, 1982; Chidester, 1986) currently working in the area of personality and performance stress the difference between amenable attitudes and non-amenable stable individual characteristics. Hansen takes this point a step further, claiming that neurotic behavior, while not necessarily composed of attitudes, is also amenable to change. Hansen claims that social maladjustment traits are resistant to modification and thus should be reliably predictive of accident involvement over time. Neurotic behavior may be a transitory result of life stresses and thus only predictive of accident involvement in the near term. Hansen does point out that neurotic behavior could persist as long as several years. Investigations looking at accident rates over time may be missing the link that an individual may be more or less prone to accidents at a particular time than at another time due to individual characteristics that operate in an unstable fashion.

Hansen suggests that neurotic personality characteristics and accident vulnerability may be modified by a third variable which he termed "distractibility." It may be that the neurotic anxious individual is easily

distracted from a task because of personal pressures. When the personal factors are eliminated, the individual may be less vulnerable to accidents. These suggestions by Hansen on the instability of neurotic tendencies and the suggestion by social psychologists (for example, Helmreich,1982) that personal attitudes which affect behavior are amenable to change, bring into serious question the traditional accident proneness view that, in order for personality characteristics to be shown to influence accident involvement, there must be stability across time. It may be important to determine which individual characteristics may result in accidents whether or not the accident behavior will be repeated. Certainly, this is essential when the accident or the preceding error can occur in extremely dangerous and unforgiving environments. A neurotic tendency or attitude that is present at a particular time, although perhaps subject to change, could influence accident or error behavior that may be catastrophic.

Hansen does not address the common thought that accident proneness will "cause" workers to be involved in accidents. He does state that individuals rarely, if ever, have consistent accidents.

In summary, Hansen's review of the literature focusing on automobile accidents and personality found the

traditional interpretation of accident proneness to be, if not discredited, worthy of reconceptualization. But, the review does not suggest that the idea that personality characteristics are linked to accident behavior be abandoned. According to Hansen, neurotic and social maladjustment behavior patterns have successfully been associated with accident involvement. Following the review of the accident literature, and based on the conclusions derived from it, Hansen developed a social maladjustment scale, and a distractibility scale which reflects neurotic tendencies. Using these scales, Hansen was able, as predicted, to identify accident involved individuals. These studies will be discussed at the end of the general review of accident proneness.

Harano, Peck, and McBride (1975) also reviewed the accident research literature and found limited support for the concept of accident proneness. They claim, as does Hansen, that the numerous attempts to identify personal characteristics which influence accident involvement are inconsistent and confusing. Harano, Peck, and McBride cite reviews (Vilardo, 1967; Haddon, Suchman & Klein, 1964; Goldstein, 1964; cited in Harano, Peck, & McBride, 1975) which conclude that attempts to uncover the relationship between person-centered variables and accident involvement have been minimally successful at

best. In contrast to this dismal view, Harano, Peck, and McBride discuss studies (Hakkinen, 1958; Shaw, 1956; and Shaw & Sichel, 1971; cited in Harano, Peck, & McBride, 1975) which Harano, Peck and McBride claim exhibit strong empirical evidence for associations between individual characteristics and accident liability.

Shaw (1971, cited in Harano, Peck, and McBride, 1975) reported impressive correlations (r = .66) using projective techniques to predict accident involvement in South African bus drivers. Shaw claims that the individual characteristics of irresponsibility, psychopathic tendencies, immaturity, lack of self-discipline, emotionality, and discontentedness relate to accident involvement. Likewise, Hakkinen (1958, cited in Harano, Peck, and McBride, 1975) was successful in demonstrating that impulsivity, inattentiveness, and rigidity are related to accident involvement.

Because their review of the literature found some promising avenues for exploration of individual differences and accident involvement Harano, Peck, and McBride, in two separate studies, focused on this issue. Both research efforts were successful in linking personality characteristics to accident vulnerability. These studies will be discussed in detail below, after Hansen's work is presented.

Hansen (1989) constructed and tested a causal model of the accident process in a industrial setting. This research was based on the hypothesis that social maladjustment traits, some characteristics of neurosis, cognitive ability, employee age, and job experience would have independent causal effects on accident involvement even when the effects of risk exposure and counseling were controlled. The variables included in the design were those associated with accidents in previous research. The criterion was a composite measure of accident behavior: the number of accidents incurred by an individual plus the number of years that the employee incurred at least one accident.

> The results showed the causal model as a whole to be viable in the initial and cross-validation analyses, and the social maladjustment and distractibility variables were found to be significant causal parameters of accidents. This study developed a new direction for future accident research by its use of causal modeling and by the creation of two new scales for the assessment of employee accident potential. (p. 81)

For the purposes of the present study on the association of individual characteristics and pilot cockpit error, Hansen's Social Maladjustment Scale was one assessment tool in the battery of predictive measures.

Adding to the evidence that individual differences play a role in accident involvement are the results of Harano, Peck, and McBride (1975). This study investigated

303 drivers and accident occurrences assessing biographical data, personality traits (ascendancy, responsibility, emotional stability, sociability, cautiousness, original thinking, personal relations, and vigor) and attitudes, parental relationships, perceptual style, perceptual motor coordination, and driving simulator performance. Results indicated that maturity, risk taking, driving attitudes, and emotional stability are associated with accidents in this population.

Psychological Stress

This project considered stress level because, based on what is known about the effects of stress on performance, it is a variable that should not be ignored.

It is noted that "Factors causing stress and ability to handle it vary greatly from individual to individual. This variation makes it virtually impossible to quantify stress and to measure its effects in a statistically valid manner" (Alkov, 1975, p. 19). Any study focusing on stress and performance, employing self-report methodology, may be plagued by response bias. "Realistically, most people are unable to be objective about their own mental state, and aviators are especially defensive about any factor that threatens their flying ability" (Alkov, 1979, p. 27).

Because of these cautions, this research project had the evaluation pilot rate the observable signs of psychological stress in the student pilot, rather than rely on a self report measure.

In keeping with the focus of this research project, this literature review centers on the few reports of stress and pilot accident involvement.

Although stress has been extensively studied to determine its impact on physical and mental health, empirical findings from studies of the relationship between stress and accident involvement have been severely limited. This paucity of investigative attention may be due to the fact that stress may be viewed as an acute, short lived situational factor which may increase a person's accident liability, but is extremely hard to "pin down" (Alkov, Borowsky, & Gaynor, 1982).

Texts discussing human factor issues usually include a section on stress and performance. Generally, it is assumed that the relationship between stress and performance assumes a curvilinear function. Minimal levels of stress are necessary to initiate behavior. With increasing levels of stress, performance is said to increase proportionately, up to a point. With high levels of stress, performance degradation occurs.

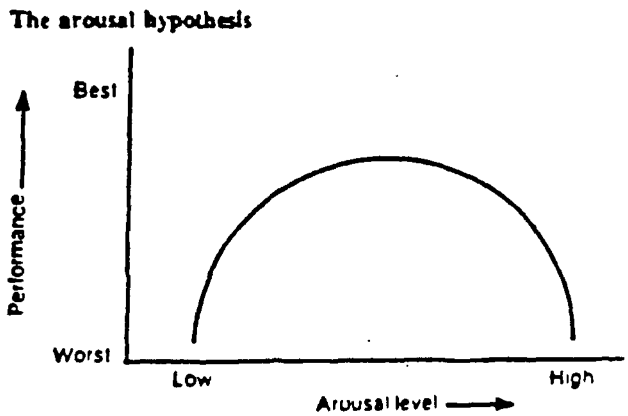
Figure 2 describes this relationship schematically, referring to this relationship as the Arousal Hypothesis which is based on the Yerkes-Dodson Law.

Life changes are viewed as physical and psychological stressors. Many studies have shown that certain life events, some offensive, some pleasant, some neutral and commonplace, are related to the onset of illness. The Holmes, Rahe "Life Change Scale" lists events that necessitate change in an individuals's life. These have been identified as events that often precede physical illness (Rahe, cited in Alkov, 1975).

Psychologically, each of these events brings about a significant change in the individual's ongoing life pattern and requires adaptive or coping behavior. Siegel and Lane (1982) suggest that when an individual must devote energy to the task of coping, performance on other tasks declines.

Alkov and Borowsky (1980) found that certain life events discriminated between those navy pilots who were causally involved in air crew error accidents and those pilots that were not causally involved. Pilots causally involved in an aircraft accident were more likely to have been involved in a recent major decision regarding career future, trouble in interpersonal relationships, demonstrated immaturity, lacked a sense of humor and

Figure 2



(Siegel and Lane, 1982)

humility, or had recently lost a loved family member or friend. Alkov, Borowsky, and Gaynor (1982) point out that many of the factors that are named on the "Life Change Event Scale" are really symptoms of stress rather than stressors themselves, and that mishaps may also be a symptom of inadequate stress-coping strategies.

This dissertation research evaluated the student pilot's psychological stress level during each helicopter check ride by having the evaluation pilot rate the presence or absence of observable physiological signs of stress in the student. A psychological stress scale was constructed by the researcher. It was not the goal of this research project to identify the source of individual stress in the student pilot's life, but to investigate the impact of stress levels on pilot performance.

CONCEPTUAL MODEL OF FACTORS INFLUENCING PILOT ERROR

Based on the academic and applied literature of aviation psychology, the following model was developed. This dissertation tested parts of this model with the goal of beginning to understand the complexity surrounding cockpit error. It was also a goal of this dissertation research to be the base for future investigative studies that will attempt to fill in the gaps left by this project.

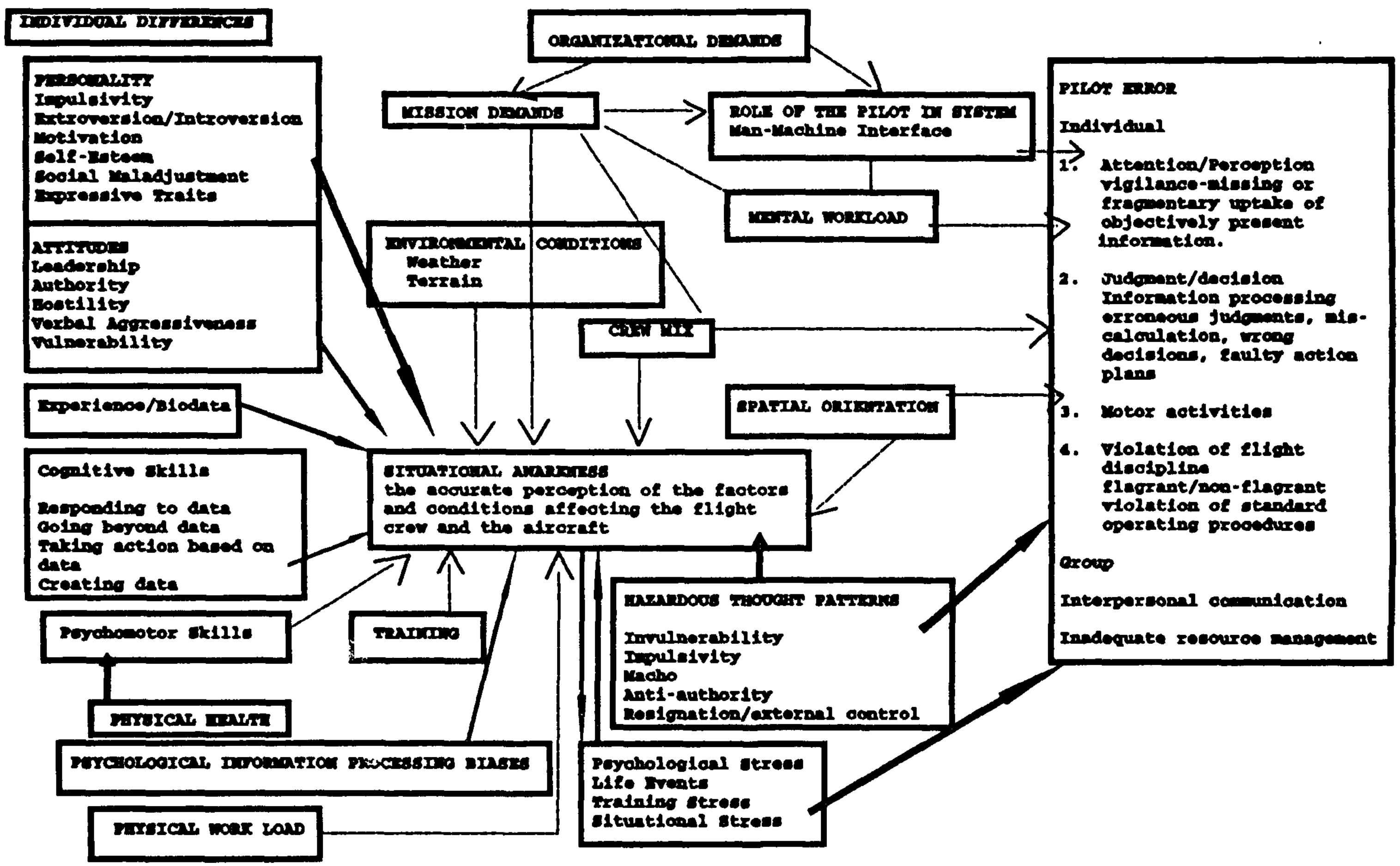


Figure 3. Proposed model of pilot error

VARIABLES IN THE MODEL

Criterion Variables

Pilot Error

Pilot error is conceptualized as falling into two broad categories: Individual pilot error and Group or crew error, each with specific subcategories. Several pilot error taxonomies have emerged from aviation psychology. For example, Fitts and Jones (1947) identified thirteen categories of error from pilot questionnaires. Ricketson (1975) identified nine categories from analysis of accident data. More recently, Gerbert and Kemmler (1986) factor analyzed critical incidents from over 1,400 pilots and found four broad categories of pilot error (attention/ vigilance; perception; cognition/decisional; motor). Because of the large sample employed and the use of the critical incident technique, this resulting error categorization (based on factor analysis), was adapted for the present research project. It was modified to include the category of violation of flight discipline (basically, disregard for standard operating procedures), as suggested by Ricketson (1975) as being a primary factor influencing pilot error caused accidents in the army pilot population,

and by Sears (1983, cited in Nagel, 1988) to be responsible for 33% of all commercial aviation accidents from 1959 to 1983. Helmreich's conceptualization of cockpit group error was also added. Thus the error categorization scheme incorporates findings from Gerbert and Kemmler's factor analytic study of cockpit error, Ricketson's analysis of Army aviation accidents, Sears analysis of commercial aviation accidents attributed to pilot error, and Helmreich's conceptualization of Crew interaction errors.

This dissertation focused on individual pilot error, specifically, errors that occur in the attention/ perception and in the judgmental/decision categories. Several analyses of pilot error caused accidents revealed that between 50% (Baing, 1983) and 87% (FAA) of pilot error falls into the area of decisional activity. Attention/perception is a critical factor leading to decisional activities; therefore, it was assessed in addition to judgement decisional errors as criteria.

This model conceptualizes pilot error as follows:

A. Individual

1. Attention/perception

a. vigilance (missing or fragmentary uptake of objectively present environmental information)

b. perception (false utilization of probability

information, usually because of environmental conditions)

2. Cognition/decision errors

   a. Poor or biased information processing, erroneous judgments, miscalculations, wrong decisions

3. Motor Activities

   a. Sensori-motor errors

4. Violations of flight discipline

   a. flagrant violation of standard operating procedures

B. GROUP

1. Interpersonal communications

2. Inadequate resource management

Mediating Variables

Situational Awareness

THE ACCURATE PERCEPTION OF THE FACTORS AND CONDITIONS AFFECTING THE FLIGHT CREW AND THE AIRCRAFT; e.g., aircraft attitude, visibility, obstructions, fuel reserve, weather conditions, etc.

Hazardous Thought Patterns

1. Anti-authority

Individual resents anyone telling them what to do. They may regard rules, regulations, and procedures as trivial or unnecessary.

2. Impulsivity

Individual may feel the need to do something, anything, immediately. They may not stop to think what they are about to do; they do not select the best alternative, preferring to act quickly.

3. Invulnerability

Individual may feel that accidents happen to other people, never to them. They know accidents can happen, and they know that anyone can be affected; but they never really feel that they may be involved.

4. Macho

Individual may try to prove that they are better than anyone else. They prove themselves by taking risks and by trying to impress others.

5. External control--resignation

Individual may display an external locus of control. Individual may see themselves or their behavior as not making a difference to the eventual outcome of a situation

Psychological Stress

1. Life stress

2. Training Stress
3. Situational Stress

Predictor Variables

Personality

1. Impulsiveness
2. Extroversion/Introversion
3. Motivation
4. Social adjustment/ maladjustment
5. Expressive traits (related to crew, group error, not considered in this phase of this project)
    a. interpersonal warmth and sensitivity

Attitudes

1. Overconfidence
2. Authority

The following are hypothesized to relate to crew or group error and were not considered in this phase of this project:

3. Interpersonal communication orientation
4. Delegation of duties in the cockpit

Cognitive Skills (CCAB,1988)

The Complex Cognitive Abilities Battery

Responding to data

<u>Going beyond data</u>

<u>Taking action based on data</u>

<u>Experience</u>

1. Biodata (for example, age, sex)
2. Life history (for example, previous involvement with authority, previous accident history)

<u>Other Mediating and Predictor Variables</u>

The complete model includes organizational demands, mission demands, the role of the pilot in the system, environmental conditions, mental work load, training, spatial orientation, crew mix, psychological information processing biases, physical work load, and physical health as factors influencing pilot error. An explanation of each of these factors and the possible effects on individual pilot error is not within the scope of this project. Many of these other variables are being considered in associated research. Because of this research design, using homogenous training groups, it is possible to claim that, with the exception of spatial orientation, these other variables noted above are relatively constant in this setting.

Psychomotor Skills

Not considered in this phase of research.

1. Control precision
2. Spatial orientation
3. multilimb coordination
4. response orientation
5. rate control
6. kinesthetic orientation

Physical Health

Not considered in this phase of research.

Summary of the Model

The proposed model attempts to acknowledge the multiplicity of causal interactions that should be considered in efforts to understand the behavioral phenomenon "pilot error." It describes schematically these causal linkages involving the potential relationships between characteristics of the individual and features of the environment that may induce pilot error.

Organizational climate, mission demands, the role of the pilot in the system, the particular mix of crew members, the physical work load, the mental work load, training, spatial orientation, and environmental

conditions are factors that contribute to the total flight environment and influence the pilot's perception and behavior. However, it was not possible to investigate each of these contributing factors in this single study, and as noted earlier, these variables were constant in this study. For practical reasons this research focused on a selected subset of particular personality, cognitive, and attitude variables and their potential links to pilot error.

For the criterion variable, practical considerations did not allow consideration of psychomotor errors or group errors in this phase of the project. This dissertation research focused on individual attention/perception and judgement/decision error. Violation of flight discipline behavior will be examined with respect to biodata and life experience data in the associated longitudinal phase of this research project. Violation of flight discipline behavior was not expected to occur in the presence of an observer and thus will be evaluated by different methodology in the longitudinal phase of this project. Crew error was not evaluated in this project.

HYPOTHESES AND PREDICTIONS

The proposed model of pilot error was structured into two distinct links (Figure 4). Three hypotheses were generated from this conceptual model (Figure 5).

Hypothesis 1

Personality characteristics, cognitive ability and individual attitudes will affect situational awareness, hazardous thought patterns, and psychological stress levels.

Hypothesis 2

Decreased situational awareness, increased psychological stress levels, and hazardous thought patterns will lead to attention/perception and judgement/decision errors.

Hypothesis 3

A significant relationship exists between individual difference measures (personality characteristics, cognitive ability, and individual attitudes) and pilot error, but this relationship is mediated by the variables

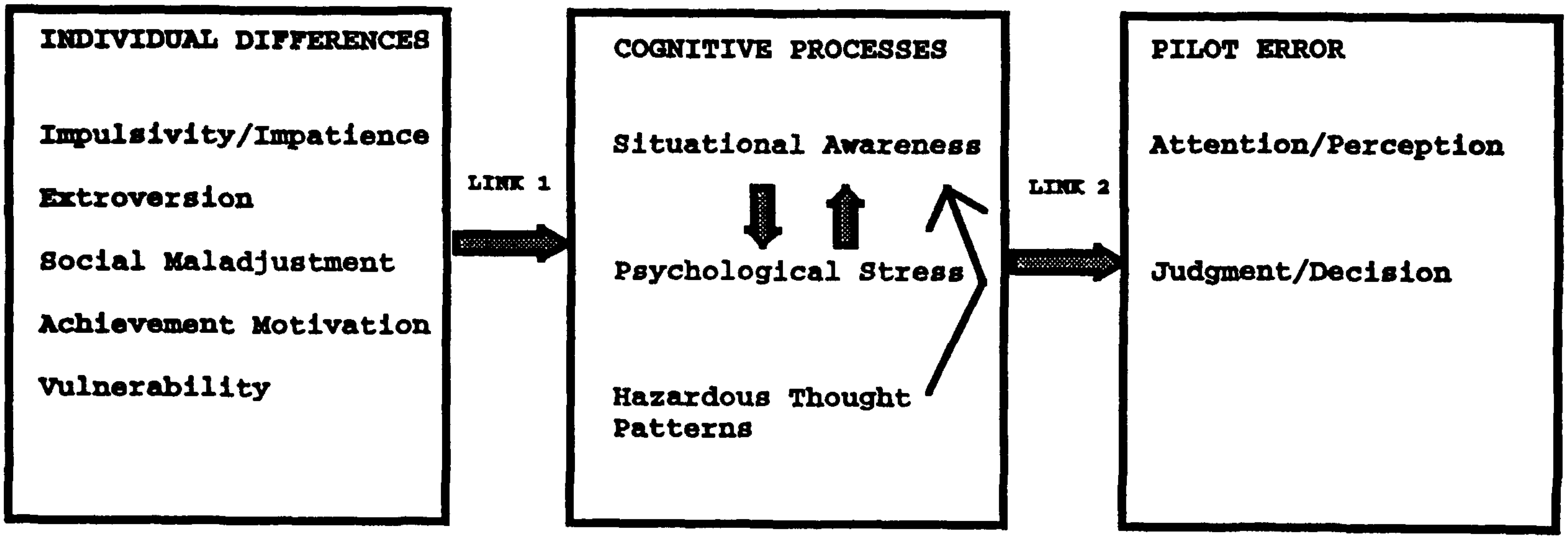
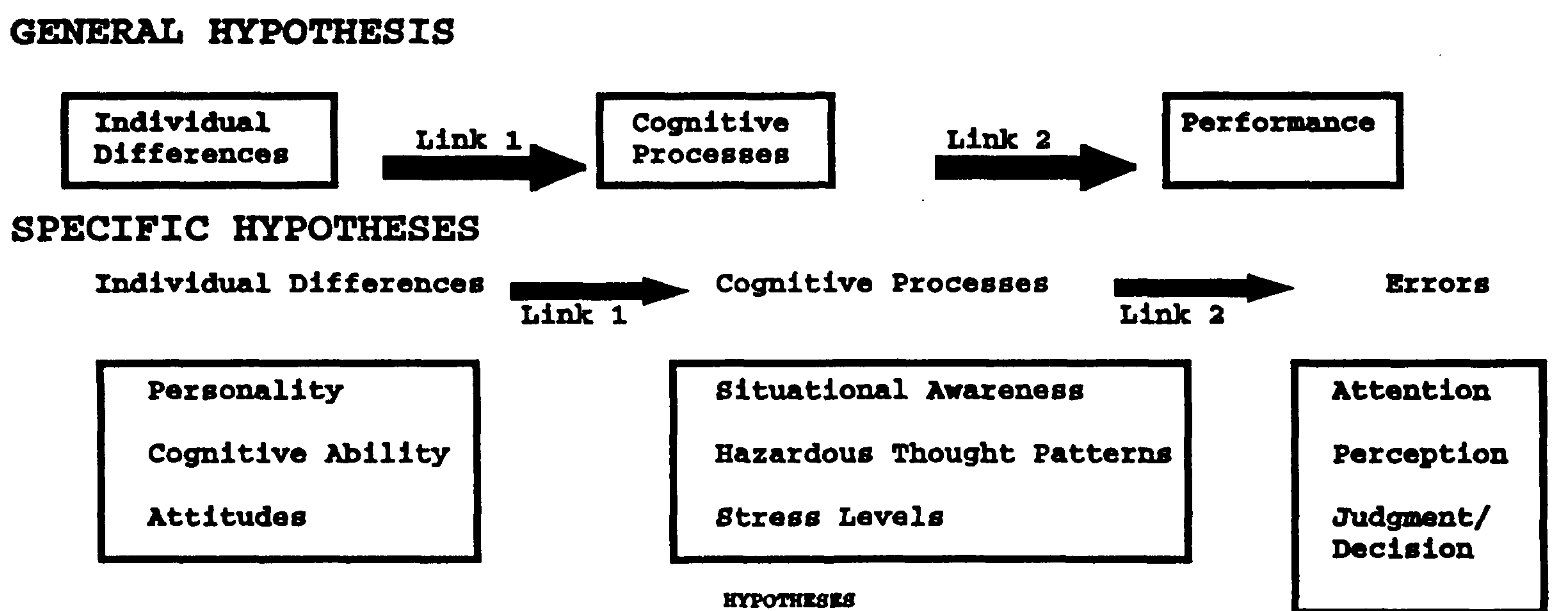

INDIVIDUAL DIFFERENCES
Impulsivity/Impatience
Extroversion
Social Maladjustment
Achievement Motivation
Vulnerability
LINK 1
COGNITIVE PROCESSES
Situational Awareness
Psychological Stress
Hazardous Thought Patterns
LINK 2
PILOT ERROR
Attention/Perception
Judgment/Decision

Figure 4



HYPOTHESES

Hypothesis 1
Personality characteristics, cognitive ability, and individual attitudes will affect situational awareness, hazardous thought patterns, and stress levels.

Hypothesis 2
Decreased situational awareness, increased psychological stress levels, and hazardous thought patterns will lead to attention/perception and judgment/decision errors.

Hypothesis 3
A significant relationship exists between individual difference measures (personality characteristics, cognitive ability, and individual attitudes) and pilot error, but this relationship is mediated by the variables situational awareness, psychological stress levels, and hazardous thought patterns.

Figure 5

situational awareness, psychological stress levels, and hazardous thought patterns.

METHOD

In presenting the proposed method and procedures to be used in this research, three terms need to be defined. **Instructor pilot** refers to training pilots that are responsible for the classroom, simulator, and practice helicopter instruction. Usually, the student pilot remains with a specific **instructor pilot** for the entire phase of the flight training program (e.g., basic instruments; advanced instruments). The **instructor pilots** are civilian pilots under contract to the United States Army. **Evaluation pilot** refers to a pilot from the Evaluations and Standards Office of the flight training center. They are veteran military helicopter pilots with extensive experience and training in evaluating students. The **evaluation pilots** are responsible for the assessment of the student pilot performance in the helicopter (referred to as a **check ride**.) These check rides must be flown successfully before the student pilot progresses to another phase of flight training or to a flight assignment.

Subjects

Three hundred twelve student helicopter pilots from the Aviation Training Center at Fort Rucker, Alabama served as subjects. This sample was drawn (by training cycle) from the total student pilot population with the following characteristics: 90% male; mean age = 23; age range 18-30. The total student pilot population, at the time of this study, was made up of 390 commissioned officers and 813 warrant officer candidates. Every commissioned officer was a college graduate, with 25% coming from West Point. Approximately 50% of the warrant officer candidates have more than two years of college education.

Different criteria for acceptance into flight training apply to the officer and warrant officer candidates. In order to be accepted for flight training, warrant officer applicants must attain passing scores on the Armed Forces Qualifications Test and the Armed Services Vocational Aptitude Battery. This is a form of quality control, as warrant officer candidates are not college graduates. The Warrant Officer applicants that pass these tests and all commissioned officer applicants must pass the Flight Aptitude Test. Generally, this test measures mechanical, spatial, and mathematical reasoning. It is purported to also assess intelligence and flight aptitude. Applicants

must score 90 or above (out of 176) to qualify for further consideration in the flight school acceptance process. After passing the Flight Aptitude Test, the successful applicants are interviewed by a panel from the flight training center as the final step in the application process.

Raters

Instructor pilots and evaluation pilots assess pilot performance and error type and frequency during specific flights. Instructor pilots and evaluation pilots have successfully completed at least one tour of duty before being considered for the instructor pilot position. After one tour of duty, the instructor pilot must complete training in evaluating flight skills and pilot performance at Fort Rucker to qualify to serve as an instructor or evaluation pilot.

Predictor Measures

During the first week of flight training the following individual differences measures were administered to the subjects:

PERSONALITY ASSESSMENT

The Eysenck Personality Inventory

The Hansen Social Maladjustment

The Helmreich Battery

INDIVIDUAL ATTITUDES

The Helmreich Battery

COGNITIVE ABILITY

The Complex Cognitive Abilities Battery

COGNITIVE STYLE

The Hazardous Thought Pattern Scale

See Appendix A for complete descriptions of specific measures.

See Appendix B for the complete measures except the Complex Cognitive Abilities Battery. This instrument was administered by personal computer to the student pilots. However, for the interested reader, the author provides a hard copy. This document is voluminous, requiring approximately 200 pages of this paper.

Criterion Measures

The two basic types of pilot error (Attention/ Perception; Judgement/Decision) were measured two times in three ways. At the end of the basic contact phase of flight training and at the end of advanced instrument flight training, criterion data was collected as follows: (1) the instructor pilot recorded the student pilot's "expected performance" prior to the check ride; (2) the

evaluation pilot rated error type and error frequency on each maneuver _during_ the helicopter check ride; (3) the evaluation pilot also rated the overall level of error _after_ the check ride was completed. Thus, each student was rated on each (of two) check rides by two raters. The instructor pilot gave a rating of expected performance for each check ride, and the evaluation pilot (blind to the expected performance rating) rated the student performance during the check ride. The evaluation pilot also rated the student pilot's level of overall error, level of situational awareness during the flight, and the observable level of psychological stress displayed by the student pilot during the check ride. (See Appendix A for detailed time line and scale descriptions.)

Description of Apparatus

The UH1 helicopter was used for student pilot evaluation.

DATA ANALYSIS

The general hypothesis that personality characteristics, cognitive ability, and attitude differences influence pilot situational awareness, cognitive style (Hazardous thought patterns), and psychological stress levels, which in turn lead to pilot error was tested using multiple regression and hierarchial regression techniques. Data analysis was done using SPSSX. Mean substitution was used to manage missing values. This is traditionally the most conservative estimate. However, comparative analyses using listwise deletion was performed with essentially identical results. For a breakdown of missing values by variable consult Appendix C.

Specifically, it was expected that stable individual differences (personality characteristics, cognitive ability, individual attitudes) affect cognitive processes (situational awareness and hazardous thought patterns) and play a role in setting pilot psychological stress levels.

1. Individual Differences--Cognitive Processes Link

For each measure of cognitive processes (Situational Awareness, Hazardous Thought Patterns, Psychological stress), a regression analysis was performed to predict that aspect of cognition as a criterion using individual difference variables as predictors. It was expected that each cognitive style measure would be significantly predicted by the individual differences measures, reflected by $R^2 > 0$. Tests of regression weights were expected to show which individual difference measure predicts which kind of cognitive process. For example, it was expected that cognitive ability should be positively related to situational awareness.

2. Cognitive Processes--Errors Link

For each criterion measure of error (attention/ perception and judgement/decision) a regression analysis was performed using Situational Awareness, Hazardous Thought Patterns, and Psychological Stress as predictors.

The analysis for Hazardous Thought Patterns used four independent HTP predictors because all five HTPs are linearly dependent as a set and therefore cannot be used in regression techniques. Based on subject matter expert judgement, the thought pattern "Resignation" was dropped out of the analysis.

It was expected that each regression would result in a significant R^2 and significant Beta weights for each predictor. In addition, the interaction of these three predictors was entered and the increase in R^2 tested. It was predicted that the increment in R^2 would be significant and the Beta weights for Stress and situational awareness interacting with Hazardous Thought Patterns would also be significant.

3. Individual Difference Cognitive Processes--Error Link

Cognitive processes (situational awareness, psychological stress, and hazardous thought patterns) mediate the affects of individual differences (personality, individual attitudes, and cognitive ability) on error performance. This was tested by hierarchial regression for each error (attention/perception and judgement/decision) criterion. Predicting each error as a dependent variable, this analysis entered the individual differences variables on the first step and then the cognitive process variables. If individual differences had predicted errors, there should have been a significant R^2 and significant Beta weights for the individual differences variables on the first step. If any of the individual difference variables still had a unique

significant Beta weight, after the cognitive process variables were entered, this would indicate an influence of that individual difference variable on error which is not totally mediated by the cognitive processes measured in this research.

RESULTS

The three hypotheses generated from the conceptual model were tested using regression techniques. Regression analyses produced inconsistent results for the hypothetical associations put forth in the proposed model of pilot error.

Hypothesis 1

Individual differences (personality characteristics, cognitive ability, and individual attitudes) would affect cognitive processes (situational awareness, psychological stress levels, and hazardous thought patterns). Link 1 in the model, addressing the relationships between individual differences and cognitive processes, were partially supported (Appendix D). Individual difference variables did not predict pilot situational awareness nor pilot psychological stress level, but were related to specific hazardous thought patterns.

The bivariate and multiple regressions were significant only for the association between the personality dimension of vulnerability and three of the cognitive style hazardous thought patterns (Table 1). In

TABLE 1

BIVARIATE REGRESSION
VULNERABILITY WITH HAZARDOUS THOUGHT PATTERNS

	Anti-Authority	Invulnerability	Impulsivity	Resignation	Macho
Vulnerability	$r = .2341$	$r = -.15008$	$r = -.1230$	$r = .1091$	$r = -.0603$
	$r^2 = .0548$	$R^2 = .0225$	$r^2 = .0151$	$r^2 = .0119$	$r^2 = .0036$
	$F(1,310) = 17.97$	$F(1,310) = 7.14$	$F(1,310) = 4.76$	$F(1,310) = 3.73$	$F(1,310) = 1.13$
	$p < .0000$	$p < .0079$	$p < .0299$	$p < .0543$	$p < .2880$

the bi-variate analyses, Vulnerability was positively related to Anti-Authority, r^2 .0548, $F(1,310) = 17.97$, $p < .0000$; negatively related to Impulsivity, r^2 .0151, $F(1,310) = 4.76$, $p < .0299$; and negatively related to Invulnerability r^2 .0225, $F(1,310) = 7.14$, $p < .0079$. Vulnerability was not related to the hazardous thought patterns of Macho nor Resignation.

Multiple regression of individual difference variables and hazardous thought patterns were non-significant except for the personality dimension Vulnerability and the hazardous thought pattern "Anti-Authority"; R^2 .0639, $F(6,305) = 3.47$, $p < .0025$. The only significant beta in the regression equation was for Vulnerability; $\beta = .2233$, $t = 3.97$, $p < .0001$ (Table 2). In this multiple regression, the other betas (cognitive ability, social maladjustment, achievement motivation, impatience, and extroversion) were all non-significant. Multiple regressions for the personality dimensions, cognitive ability, and individual differences on the other hazardous thought pattern variables were non-significant.

In summary, analyses considering the relationships between individual differences (personality dimensions, cognitive ability, individual attitudes) and cognitive processes (situational awareness, psychological stress, and hazardous thought patterns) were largely non-

TABLE 2

MULTIPLE REGRESSION
INDIVIDUAL DIFFERENCES ON THE HAZARDOUS THOUGHT PATTERN
Dv = "Anti-Authority"

$R^2 = .0639$, $F(6,305) = 3.4720$, $p < .0025$

Independent Variable	BETA	t-test	p <
Cognitive Ability	.0369	.663	.5000
Social Maladjustment	.0221	.358	.7208
Achievement Motivation	-.0025	- .045	.9638
Vulnerability	.2233	3.972	.0001
Impatience	.0411	.705	.4821
Extroversion	-.0775	-1.299	.1949

significant. Only the personality dimension "vulnerability" was related to the hazardous thought patterns of anti-authority, impulsivity and invulnerability. Hypothesis 1 was generally not confirmed.

Hypothesis 2

Decreased situational awareness, increased psychological stress levels, and hazardous thought patterns will lead to attention/perception and judgement/decision errors.

Link 2 in the model, addressing the relationships between cognitive processes (situational awareness, psychological stress, and hazardous thought patterns) and pilot cockpit error, found significant relationships between situational awareness and pilot error and between psychological stress and pilot error (Table 3) but no significant relationships between the hazardous thought pattern variables and pilot error (Appendix E). Bivariate regression analyses showed, as expected in hypothesis 2, (1) that pilot situational awareness is negatively related to attention/perception error, r^2 .1315 $F(1,310) = 46.97$ $p > .0000$, and negatively related to judgement decision error, r^2 .1454, $F(1,310) = 52.77$, $p < .000$; (2) that pilot psychological stress level is positively related to

TABLE 3

REGRESSION MODELS FOR COGNITIVE PROCESSES TO PREDICT PILOT ERROR: Basic and Advanced Phases of Flight Training
LINK 2

BI-VARIATE REGRESSION
N = 312, Missing Values = Mean Substitution

Situational Awareness to predict Attention/Perception Error:
$r^2 = .1315^*$, $F(1,310) = 46.97$, $p < .0000$
Situational Awareness to predict Judgment/Decision Error:
$r^2 = .1454^*$, $F(1,310) = 52.77$, $p < .0000$
Psychological Stress to predict Attention/Perception Error:
$r^2 = .1467^*$, $F(1,310) = 53.33$, $p < .0000$
Psychological Stress to predict Judgment/Decision Error:
$r^2 = .2165^*$, $F(1,310) = 85.69$, $p < .0000$

MULTIPLE REGRESSION
N = 312, Missing Values = Mean Substitution

Independent Variable	BETA	t-test	p <
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT JUDGMENT/DECISION ERROR			
$R^2 = .2917^*$, $F(2,309) = 63.65$, $p < .0000$			
Psychological Stress	.3949	7.990	.0000
Situational Awareness	-.2831	- 5.728	.0000
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT ATTENTION/PERCEPTION ERROR			
$R^2 = .2230$, $F(2,309) = 44.34$, $p < .0000$			
Psychological Stress	.3122	6.030	.0000
Situational Awareness	-.2850	-5.506	.0000
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, HAZARDOUS THOUGHT PATTERNS PREDICTING ATTENTION/PERCEPTION ERROR			
$R^2 = .2238^*$, $F(6,305) = 14.66$, $p < .0000$			
Impulsivity	-.0235	- .392	.6957
Stress	.31200	5.982	.0000
Anti-Authority	-.0048	- .086	.9314
Macho	.0235	.414	.6790
Situational Awareness	-.2882	-5.500	.0000
Vulnerability	.0007	.012	.9908

TABLE 3--continued

Independent Variable	BETA	t-test	$p <$
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, AND HAZARDOUS THOUGHT PATTERNS AND JUDGMENT/DECISION ERROR			
$R^2 = .2959$, $F(6,305) = 21.36$, $p < .0000$			
Impulsivity	-.0542	- .947	.3444
Stress	.3953	7.959	.000
Authority	-.0305	- .575	.5659
Macho	-.0431	- .796	.4265
Situational Awareness	-.2899	-5.808	.0000
Vulnerability	.0007	.013	.9896

attention/perception error, r^2 .1467, $F(1,310) = 53.33$, $p > .0000$, and positively related to judgement/decision error, r^2 .2165, $F(1,310) = 85.69$, $p > .0000$.

Multiple regression analysis showed that the combination of pilot situational awareness and pilot psychological stress level affect the frequency of attention/perception errors, R^2 .2230, $F(2,309) = 44.34$, $p > .0000$, and affect the frequency of judgement/decision errors, R^2 .2917, $F(2,309) = 63.65$, $p > .0000$. For Attention/Perception error, the standardized beta weight for situational awareness is -.290 ($t = -5.506$, $p < .01$), suggesting that low levels of situational awareness are related to more frequent attention/ perception errors. For judgement/decision error, the standardized beta weight for situational awareness is -.290 ($t = -5.728$, $p < .01$) suggesting that low levels of situational awareness are also related to more judgement/decision errors.

For attention/perception error, the standardized beta weight for psychological stress is .3122 ($t = 6.030$, $p < .01$), suggesting that higher levels of pilot psychological stress are related to more frequent attention perception errors. For judgement/decision error, the standardized beta weight for psychological stress is .3949 ($t = 7.990$, $p <. 01$), suggesting that higher levels of psychological

stress are related to higher levels of judgement/decision errors.

The other cognitive process variables considered in the proposed model to affect pilot error, the hazardous thought patterns, did not reveal any significant relationships with either attention/perception or judgement/decision error. None of the hazardous thought patterns assessed were significantly related to either attention/perception or judgement/decision errors. Further, the multiple regressions including the effects of hazardous thought patterns on pilot error did not show these variables to be significant predictors.

It was also hypothesized that the cognitive process variables may interact to affect pilot error in a way that each variable in isolation might not. The effects of the interaction of the cognitive processes variables on pilot error was tested using hierarchial regression techniques (Appendix F). These analyses showed, as did the other regression analyses, that situational awareness and psychological stress are the critical variables affecting attention/perception and judgement/decision error. None of the interaction variables, created from the cognitive process variables, contributed significant predictive power to the regression model once situational awareness and psychological stress were in the equation.

Additionally, the interaction of situational awareness and stress did not significantly increase the R^2 in predicting either kind of pilot error.

In summary, these analyses employed three levels of statistical investigation: (1) the cognitive processes variables to pilot error, (2) the cognitive processes variables and the interaction for situational awareness and stress and pilot error, and (3) the cognitive processes variables and the interactions of each to pilot error. F tests for the differences in R^2 between the three levels of analyses were all non significant.

Hypothesis 3

Hypothesis 3 posited that a significant relationship between individual differences (personality dimensions, cognitive ability, and individual attitudes) and pilot error would be mediated by the cognitive processes variables (situational awareness, psychological stress levels and hazardous thought patterns). Hierarchial regression was used to test these possible complex associations. Results of the analyses did not support this hypothesis (Appendix G). The first step of the analysis investigated the effects of individual differences on pilot error, resulting in non significant associations for each type of pilot error. The second

step of the analyses added the cognitive process variables, resulting in significant regression weights predicting each error type. Regression analyses for individual differences (personality dimensions, cognitive ability, and individual attitudes) to predict attention perception error resulted in R^2 .0233, F (6,305) = 1.21, p < .2978. When the cognitive processes variables (situational awareness, psychological stress, and hazardous thought patterns) were entered on the second step, R^2 .24615, F (12,299) = 8.13, p < .0000 resulted. F test for the difference in these R^2 was significant. F (6,299) = 48.81, p < .05.

Similarly, when individual differences (personality dimensions, cognitive ability, and individual attitudes) were entered on the first step of the analysis to predict judgement decision error, R^2 .0163, F (6,305) = .8422, p < .5381 resulted. When the cognitive process variables (situational awareness, psychological stress, and hazardous thought patterns) were added on the second step to predict judgement decision error, R^2 .3092, F (12,299) = 11.15, p < .0000 resulted. The F test for the difference in these R^2 was significant F (6,299) = 21.21, p < .05.

Thus, considering each error criterion (attention/ perception, judgement/decision), the individual difference variables (personality dimensions, cognitive ability, and

individual attitudes) were not predictive, and a significant portion of the variance was accounted for only after the cognitive process (situational awareness and psychological stress) variables were entered into the analyses.

Analyses investigating the possibility that individual difference variables (personality dimensions, cognitive ability, and individual attitudes) may mediate the relationship between situational awareness and psychological stress to pilot error again demonstrated that the individual difference variables did not contribute significant predictive power to the regression model. Hierarchial regression analyzing the mediating effects of the individual difference variables with situational awareness and psychological stress predicting attention perception and judgement decision error showed that the individual difference variables did not account for a significant portion of the remaining variance after situational awareness and psychological stress were entered into the equation. Predicting attention perception error with situational awareness and stress, R^2 .2230, $F\ (2,309) = 44.34$, $p < .000$, adding the individual difference variables to the equation, R^2 .2448, $F\ (8,303) = 12.27$, $p < .0000$. Predicting judgement decision error with situational awareness and stress, R^2 .2917, $F\ (2,309)$

= 63.65, $p < .0000$, adding the individual difference variables to the equation, R^2 .3060, $F(8,303) = 16.70$, $p < .0000$. These analyses again demonstrate that the cognitive process variables of situational awareness and psychological stress, do affect the frequency of pilot error with little or no influence from the individual difference variables.

Post Hoc Analyses

Lisrel

Post hoc analyses of the data confirmed the findings of the regression analyses. Lisrel path analysis of the model (Appendix H) generally substantiated the regression results. Using maximum likelihood estimation, the Lisrel analysis indicated a moderately poor fitting model; adjusted goodness of fit = .53, chi square ($df = 34$) = 626.78, $p < .01$. According to the modification indices, a path should exist between attention/perception and judgement/decision error. This suggests that the criterion error measures (Attention/perception and Judgement/decision) composed a single factor rather than two distinct constructs as measured in this study. This duplicates the results from the simple correlations of the error types, $r^2 = .7580$, $p < .0000$ (Appendix D). However, it could also indicate that there are distinct error

constructs but that the measures used in this study do not adequately tap them.

Regression Analysis of Basic vs. Advanced Instrument Phases

The advanced instrument phase of flight training assumes mastery of basic flight skills and inherently presents the student pilot with many judgement/decision making opportunities absent during the basic flight phase of pilot training. Thus, separate analysis of error data for each phase of flight training seemed appropriate. Division of the criterion data into the two phases of flight training (Basic flight and Advanced Instruments) and applying regression analyses to each phase of training separately, essentially duplicated the results of the analyses when the data was considered as one sample (Appendix I). The three hypotheses generated from the proposed model of pilot error were tested for each flight phase independently, yielding essentially the same results as did the analyses of the unified data.

Link 1 of the proposed model, the relationship between individual differences and cognitive processes, was not totally reanalyzed. The relationship between individual differences and hazardous thought patterns was not reanalyzed, as these variables were assessed only once, at

the beginning of flight training. The influence of personality dimensions, cognitive ability, and individual attitudes on hazardous thought pattern development was not considered to be different depending on the phase of flight training. The associations between individual difference variables and situational awareness and psychological stress variables were analyzed, and the outcome duplicated the non-significant results obtained when the data was considered as one sample.

Link 2, the relationship between cognitive processes and pilot error, was reanalyzed for each phase of flight training (basic and advanced instruments) separately (Appendix I and Table 4). The results showed that the effects of cognitive processes on pilot error were basically the same for both phases of flight training, and basically the same as when the two flight phases were merged as originally analyzed. Results of Phase 1 nearly duplicated results of Phase 2. Situational awareness was negatively related to attention perception error, r^2 .0634, $F(1,310) = 21.02$. $p < .0000$ in phase 1 and r^2 .1489, $F(1,310) = 54.25$, $p < .000$ in phase 2; and negatively related to judgement decision error, r^2 .0643, $F(1,310) = 21.31$. $p < .000$, in phase 1 and r^2 .1423, $F(1,310) = 51.44$, $p < .0000$ in phase 2. Psychological stress was significantly related to attention perception error, r^2

TABLE 4

REGRESSION MODELS: SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS TO PREDICT PILOT ERROR

BI-VARIATE REGRESSION
N = 312
Missing Values = Mean Substitution

	BASIC + ADVANCED		BASIC (Phase 1)		ADVANCED (Phase 2)	
RELATIONSHIP	r	F(1,310)	r	F(1,310)	r	F(1,310)
SA--ATT/PER	.1315*	46.97	.0634	21.01	.1489	54.25
SA--JUD/DEC	.1454*	52.77	.0643	21.31	.1423	51.44
PS--ATT/PER	.1467*	53.33	.1481	53.89	.1272	45.19
PS--JUD/DEC	.2165*	85.69	.2149	84.89	.1608	59.41

SA = Situational Awareness
PS = Psychological Stress
ATT/PER = Attention/Perception Error
JUD/DEC = Judgment/Decision Error

*p < .0000

.1481, $F(1,310) = 53.89$, $p < .0000$, in phase 1 and r^2 .1272, $F(1,310) = 45.19$, $p < .000$ in phase 2; and significantly related to judgement decision error, r^2 .2149, $F(1,310) = 84.89$, $p < .0000$ in phase 1 and r^2 .1608 $F(1,310) = 59.41$, $p < .0000$, in phase 2. These results are very similar and the conclusions indistinguishable from those attained when the data was considered as one sample. Although the correlations appear to shift from one phase to another and from the combined data to the segmented data, a test of the differences between correlations using Fisher's r to Z transform did not reveal any significant differences in the correlations.

The interaction of the individual difference variables and cognitive processes on pilot error was not reanalyzed for each phase of flight training separately. In view of the nearly identical results for phase 1 and phase 2 with the results of the entire sample in the forgoing analyses, it seemed redundant and trivial to continue to pursue this line of analysis.

Chi-Square

In an attempt to uncover factors that may contribute to levels of psychological stress in individual student pilots, the possible effects of different evaluation

pilots were considered. It is possible that individual evaluation pilots may induce unique stress on student pilots because of personal characteristics or ways of interacting with the student taking the check ride. Chi-square analysis of evaluation pilot by pilot stress level did not show a difference in stress level due to evaluation pilot (Appendix J), Pearson Chi-square = 123.04 ($df = 105$), $p < .1101$. Thus, it can be concluded that in this study, pilot stress level was not strongly affected by the characteristics of the evaluation pilot.

Coefficient Alpha

The internal consistency of the error criterion measures was investigated using Reliability coefficients: attention perception error, Alpha = .6066 and for judgement/decision error, Alpha = .4136. These results suggest that each measure of error appears to be consistently measuring the same behavioral dimension.

However, given the .75 correlation between the types of error, it is possible that they are more consistent with each other than they are internally consistent.

Correlation

Because the analysis did not indicate a significant relationship between overall cognitive ability and

situational awareness and psychological stress, further correlational analyses were performed on each component of the cognitive ability composite. These results indicated that each component of cognitive ability (taken separately) could still not predict situational awareness or psychological stress level. However, the individual score on the tower puzzle component of the cognitive ability battery did correlate with psychological stress level, r^2 .1241, $p < .024$. The tower puzzle component of the cognitive ability battery measures the individual's planning, situation assessment, decision making, and problem solving dimensions. The negative correlation between these two variables indicates that the lower the score on the tower puzzle component, the higher the pilot psychological stress level during the checkrides. However, given the number of correlations run in these analyses, the significance of this finding is questionable.

DISCUSSION

The principal issue in this study was the influence of individual differences (personality dimensions, cognitive ability, and individual attitudes) on the type and frequency of pilot cockpit error. It was hypothesized that the relationship between individual differences and pilot error would be mediated by cognitive processes (situational awareness, psychological stress, and hazardous thought patterns). It was specifically expected that personality characteristics, cognitive ability, and individual attitudes would affect situational awareness, pilot psychological stress levels, and hazardous thought pattern tendencies; and subsequently that these cognitive processes would affect the type and frequency of pilot cockpit error. It was anticipated, for example, that (a) higher levels of cognitive ability would be significantly related to increased levels of situational awareness; (b) that social maladjustment would be related to the specific hazardous thought patterns of invulnerability and/or anti-authority; (c) that social maladjustment would be related to decreased situational awareness; and (d) that the high need for achievement

would be related to increased psychological stress levels. These expectations were based on the suggestions put forth in the appropriate theoretical and applied literature cited earlier in this paper.

The three hypotheses--individual differences would affect cognitive processes, cognitive processes would affect pilot error, and cognitive processes would mediate the affects of individual differences on error performance-- were partially confirmed by the data from this present study. For the first hypothesis, results showed only one significant relationship between the individual difference variables and cognitive processes. The personality dimension of vulnerability was related to the hazardous thought patterns of invulnerability, anti-authority, and impulsivity. However, the expectations that cognitive ability would be related to situational awareness, that social maladjustment would be related to invulnerability, anti-authority, or situational awareness, and that achievement motivation would be related to psychological stress levels were not confirmed in this study.

Vulnerability

The relationship between the personality dimension of vulnerability and specific hazardous thought patterns is

somewhat unexpected. The positive relationship between vulnerability and anti-authority seems intuitively reasonable. Vulnerability as assessed in this study addresses the individual's tendency to feel that a particular outcome could or might happen personally. More appropriately, the scale should be referred to as invulnerability. The scale measures the individual's tendency to feel that an unfortunate event will not happen to them. High scores on the scale indicate the tendency to feel that unfortunate events are not likely to happen to the particular individual.

Such an individual that does not personalize the possibility of an unfortunate event may also reflect an anti-authority cognitive style, as this study showed. Authority usually represents a set of rules or guidelines intended to direct individual behavior. It may be that individuals who feel invulnerable view rules as too restrictive and, because they feel that unfortunate events will not happen to them, rules to safeguard individuals in the environment are not meant for them or are totally unnecessary. It also may be that individuals with an invulnerable personality may feel that rules made by authorities are not as appropriate as rules that the individual personally develops and prefers.

The negative relationship between the personality dimension, vulnerability and the cognitive style variable, invulnerability, is more difficult to explain. The terms are different, but the scales claim to measure the same individual tendency. Since scores from the two separate scales assessing "vulnerability" were negatively correlated, it suggests that either the scales are not measuring the same dimension or that the personality dimension of invulnerability does not necessarily mean that the individual then possesses an invulnerable cognitive style. This second option seems unlikely. It is probably more accurate to suggest that one or both of the assessment scales is fraught with psychometric difficulties. A definitive explanation for these incongruous results is not possible from the present data.

The negative relationship between the personality variable vulnerability and the cognitive process variable impulsivity is, at first consideration, somewhat counter-intuitive. It might be expected that the invulnerable individual would be less patient in actions due to the confidence that unfortunate events probably will not occur. The fact that the data show that individuals possessing invulnerable personality dimensions also tend to be less impulsive may reflect a confidence from a different perspective. Possibly the invulnerable

individual develops and maintains personal confidence because the individual carefully weighs most aspects of a situation before taking action, resulting in success. Thus, the tendency towards overconfidence may be partially based on past victories attributed to careful examination of environmental situations. Consequently, the personality dimension of invulnerability may be enhanced by past successful experiences and preparation, leading the individual to adhere to non impulsive strategies.

However, in present work, the relationship between invulnerability and impulsivity was demonstrated in the population of unexperienced student pilots that were assessed on the first day of flight training. Thus, this relationship is due to individual differences and is not the result of training. It has been suggested by subject matter experts (for example, Lofaro 1991, personal communication) that experienced aviators operate in highly structured ways. This leads the typical aviator to have strong feelings of invulnerability due to the ability to apply prior training and experiential learning with successful results. Lofaro claims that this makes aviators less prone to act in impulsive ways; rather, they fall back on their standard operating procedures, training, etc. The significant correlations between invulnerability and impulsivity found in this non-trained

student pilot population suggest that the Army selection system seems able to select non-trained individuals that possess at least similar characteristics to experienced Army pilots. Interestingly, the selection system does not specifically assess personality variables in the screening process with paper and pencil measures. The interview may be the means of identifying these characteristics. If this is the case, it speaks to Bernardin and Bownas' (1985) claim that even when organizations state that they do not use paper and pencil personality assessment to screen job applicants, in fact, interviews do assess individual personality characteristics which are used as selection criteria. The results of this study, indicating that the Army pilot selection system may in some way be assessing personality dimensions inadvertently, should alert this community to the need to explore this possibility more thoroughly. Bernardin and Bownas also claim that if an organization is going to use personality assessment (even the inadvertent interview form) the organization should recognize this process and attempt to follow valid procedures for such assessment.

Unfortunately, the cognitive process variables, anti-authority, invulnerability, or impulsivity, did not predict type or frequency of pilot error. Thus, even though this study was able to demonstrate a personality-

cognitive process link, the study was not able to explain how or even if personality and cognitive style affect error behavior. From this study, it is possible to conclude that the personality dimension invulnerability is related to cognitive style and specifically cognitive styles centering on anti-authority, and low impulsivity, but not how anti-authority and impulsivity relate in turn to pilot error.

Thus, it is not clear whether the invulnerable personality, that has developed a non impulsive or anti-authority cognitive style, actually manifests differential error type and frequency rates. This aspect of personality and behavior should be investigated more thoroughly in future research efforts.

Pilot invulnerability has long been considered a trait that would eventually lead to difficulty in flight (Ricketson, United States Army Aviation Safety Center, personal communication, 1988). The results from the present study could begin to challenge that assumption. However, the missing link to pilot performance needs to be established by further research before any conclusions can be drawn or before the bias against overconfidence (invulnerability) will be dispelled.

Addressing the second hypothesis, the influence of cognitive processes (situational awareness, psychological

stress level, and hazardous thought patterns) and pilot error, this study found that situational awareness and psychological stress are related to the frequency of each type of pilot error. This finding empirically demonstrates what had previously only been anecdotally suggested. The criticality of situational awareness and psychological stress in safe flight, a formerly intuitive conclusion, gains validity based on the results of the present study.

Situational Awareness

The prevalent notion that faulty situational awareness provides inaccurate environmental information to the pilot, which complicates judgement and subsequent decision making, is strengthened by the data from this study. The results demonstrated a significant negative relationship between pilot situational awareness and pilot attention perception and judgement decision error, which had not previously been empirically established.

The finding from this study that pilot situational awareness is related to pilot attention/perception error was anticipated. Intuitively, the association between situational awareness and attention appears symbiotic. The concept of situational awareness embodies attentional processes. It is unlikely that adequate situational

awareness will be attained and maintained without an appropriate attention level. Since, this study showed, situational awareness is related to attention/perception and judgement/decision error and the analyses suggested that these errors are related, it should be noted that these three human activities appear to be closely integrated. These findings suggest that pilot environmental awareness level is related to the "quality" of subsequent judgements and decisions. Thus it has been empirically demonstrated that situational awareness does predict pilot cockpit error.

However, several questions concerning the antecedents of situational awareness remain unanswered. The role of individual differences that may affect the acquisition of appropriate situational awareness remains murky. It has not been demonstrated that individual differences (personality, cognitive ability, and individual attitudes) may play a role in the development of situational awareness.

Drawing from the ideas generated from the past research and presented in the literature review of this paper, it was anticipated that motivational forces, impulsive tendencies, and extroverted personality characteristics may prejudice an individual's situational awareness and ultimately influence attention/perception

and judgement/decision errors. These relationships were not demonstrated in the present study. Further, it has been suggested that situational awareness, the perception of the factors and conditions that affect the aircraft and flight crew, is the result of a chain of information processing events (Gerbert & Klemmer, 1986, cited earlier in this paper). This generated the assumption that cognitive ability should affect situational awareness, since cognitive ability generally affects information processing (Posner, 1986). The findings from this study did not support that assumption. The lack of a demonstrated link between cognitive ability and situational awareness could be due to the restricted range of cognitive ability scores appearing in this population of student pilots. However, this is not the case for the lack of demonstrated relationship between the other individual difference (personality and attitudes) measures and cognitive processes. The personality and attitude measure scores were normally distributed in this population. The cognitive ability scores reflected a restricted range. This is probably due to the fact that student pilots are screened prior to acceptance to flight training. Cognitive ability is one of the individual dimensions assessed, and flight school selection is based on these scores. The higher the cognitive ability score,

the better chance of being selected for flight training. Thus, the applicants with the highest cognitive ability scores will be selected for flight school. This results in a restriction of range for cognitive ability in this student population. The lack of the full distribution of cognitive ability scores in this population may mask the true relationship between cognitive ability and the development of situational awareness of the flight environment. Correlational techniques are not totally successful when the full range of a distribution is not present.

In addition to the restricted range in the cognitive ability scores, the five point rating scale used to assess situational awareness may not have been sensitive enough to discriminate subtle differences in the pilot population. Thus prediction, in this case, is doubly difficult. However, use of the rating scale did demonstrate that different levels of pilot situational awareness do exist within the student pilot population and that these differences are related to pilot cockpit error frequency. It is unlikely that future research efforts will be able to avoid the restricted range problem, as future pilot selection criteria will not differ from the current standards. Research efforts will continue to be confronted with cognitive ability range restrictions and

should concentrate on developing instruments that are sensitive enough to handle the range restrictions yet sensitive enough to assess subtle differences in situational awareness.

Thus, from the results of this study it can be concluded that different levels of pilot situational awareness are associated with pilot performance. However, it still remains to be shown which individual difference variables actually play a role in the acquisition of appropriate situational awareness.

The present results cannot explain which human activities are responsible for the acquisition of situational awareness. The study was not designed to assess the cognitive activities that contribute to or take away from situational awareness. Nor can these results explain the exact sequence of events leading to poor situational awareness and pilot error. The study was not designed to address these issues. No attempt was made to identify the cognitive processes which act to generate situational awareness. The intention was to define situational awareness in order to assess overt levels of situational awareness occurring in this pilot population. Thus, this study operationally defined situational awareness according to prevailing doctrine in the aviation

community to guide evaluation pilot ratings of the student pilot's level of situational awareness.

In this applied research setting, using non professional raters, the microscopic level of evaluation necessary to investigate the cognitive processes underlying situational awareness and/or to differentiate the temporal or sequencing of events leading to situational awareness was not possible. Follow-up research should strive to recognize the precise cognitive processes (i.e., input from vision, auditory, vestibular systems, air traffic control input, environmental input, etc.) employed in creating pilot situational awareness. When this is accomplished, such information should contribute to the methodological base for investigating factors which impact negatively or positively on these processes. Then it may be established how the beneficial factors can be emphasized and enhanced and the negative factors minimized in attempts to increase situational awareness and ultimately flight safety.

The current research was not compatible with designs that would have allowed for computer driven and recorded flight scenarios that could then be analyzed for errors and the precipitating events to each error. It was conducted real time in operational Army helicopters. Future simulator research should consider event sequencing

methodology when confronting situational awareness and pilot error.

It should also be noted that the evaluation pilot rated the student pilot on both the predictor (in this case, situational awareness and psychological stress) and also rated the criterion (in this case, pilot error). The results, while encouraging in that it was possible to demonstrate a link between cognitive processes and pilot error, should be viewed with some caution. It may be possible that a portion of the variance accounted for by the cognitive style measures (situational awareness and psychological stress) was due to method variance.

Although method variance should be considered, it should be noted that multiple regression showed that the variables situational awareness and psychological stress each uniquely contribute to each type of pilot error. Thus, the evaluation pilots do distinguish between pilot situational awareness level and pilot psychological stress level. Further, this study collected an independent rating of pilot error from the instructor pilots. These ratings were not known to the evaluation pilots prior to the student checkride. The instructor pilot's expected error ratings of the student pilot (based on overall performance during that particular phase of training) correlate with the evaluation pilot's ratings of error

during each checkride. Additionally, regression analyses demonstrated significant relationships between evaluation pilot situational awareness ratings and the instructor pilot's ratings of expected student pilot error, and for evaluation pilot rating of psychological stress and instructor pilot's rating of expected student pilot error (Appendix K).

Psychological Stress

Data from the present study substantiate the general findings derived from stress and performance research in other settings. Previous research has shown that psychological stress levels are related to performance in a curvilinear function. The arousal theory states (cited earlier in this paper and based on the Yerkes-Dodson Law) that minimal levels of stress are beneficial to performance; with increasing levels of stress, performance degradation occurs. Although in the present investigation stress levels were significantly related to pilot cockpit error, this relationship appears linear and negative; the higher the level of stress, the higher the errors. The data did not show that at the lowest levels of stress pilot performance was better than when stress level increased, as the arousal theory would suggest.

It is possible to put forth two explanations for these results. First, these findings may reflect the fact that in this check ride situation the portion of the curve of performance that this study sampled was the low side of the curvilinear relationship, when higher stress level adversely affects performance. In this case, the data substantiates the research findings from the other performance domains.

Second, the present findings may reflect the fact that the relationship between stress and performance in the cockpit may be different than the relationship of stress and task performance in other domains. It may be that the stress of the checkride (because of its importance) and the evaluation pilot's presence simply prompts error frequency to increase in those pilots vulnerable to such an influence. It may not be that when lower (minimal) levels of stress occur in this performance domain that the expected initial increase in performance follows.

Additionally, these findings could be due to insensitivity of the metric used to evaluate stress levels and/or the lack of discrimination ability of the evaluation raters. The five point rating scale may not be discriminating enough to capture the curvilinear performance function found from other performance domains.

Further, such a finding could be due to rater biases which occur when using rating scales and subjective measures of behavior. Failure to use the end points on the scale, halo, characteristics of the rater, or some ambiguity in rating a behavior or state that is being inferred are some constraints that must be considered when using non professional raters in an applied setting. Given all the possible biases, the present study was still able to demonstrate a relationship between psychological stress and pilot error. Future research investigating stress and pilot error should consider more stringent and objective measures (possibly physiological) of psychological stress. These measures combined with the computer generated error scores would present a more precise view of stress and pilot performance.

Personality, Individual Attitudes

This study attempted to address the major, long standing criticisms of personality performance research, in general, and the important criticisms of personality performance research in aviation settings in particular.

One of the criticism of personality performance research centers on the choice of assessment tools. In organizational settings implementing personality performance research, often clinical instruments are used

as assessment tools. The major problems that arise with this methodology were presented in the literature review section of this paper. These concerns, of using clinically validated measures in a non clinical setting, were addressed in this study. Only instruments that had previously been validated with various accident behavior criteria were designated as assessment tools in this present study. The Eysenck Extroversion scale, the Social Maladjustment scale, and the Helmreich Battery are well respected and often-used measures in attempts to study human performance and specifically accident involvement.

Also, Epstein and O'Brien's (cited earlier) claim that it may not be possible to predict a single occurrence of behavior using personality assessment was heeded in this study. Epstein and O'Brien suggest that aggregated measures, rather than isolated incidents, of behavior will allow a cogent view of individual functioning. The present study utilized several measures of the pilot error criterion collected over several observations by several rating sources. These criterion measures were aggregated to reflect a stable representation of pilot error for each subject.

More specifically to aviation research, the present study considered two criticisms of past pilot performance

research: training criteria and post hoc analyses of accident involvement.

Several aviation researchers (for example, Helmreich, 1982; Dolgin & Gibb, 1988, cited earlier in this paper) have stated, quite emphatically, that performance studies employing pass/fail or training grades as criterion are doomed to failure. Restricted range is a weighty problem induced by the design of flight training programs. Flight training programs are not designed to differentiate among the student pilot population beyond an acceptable level of performance. Basically, whether apparent or not, these programs operate on a pass or fail system. Thus, to be able to predict successful performance using individual differences, such as personality or attitudes is very difficult. Difficult though it may be, it is extremely important, because in military settings high rates of costly pilot attrition occur. Failure to succeed in a pilot training program is not only significantly costly to the training establishment, but it can be extremely costly, psychologically, to the student that is dismissed. Thus, aviation communities, and the military in particular, strive to develop selection systems that can predict pilot training performance. Research will continue in these directions, and efforts to either solve the restricted range problem, or to develop instruments

capable of discriminating variability in performance are necessary. It is important to note that the present study did not employ pass/fail nor training grades as criterion. The choice of pilot error as the criterion variable is a step towards attaining more variability in performance measurement, especially in military student pilot populations.

Another source of potential range restriction for pilot populations occurs when prior selection measures are subsequently used to try to predict pilot performance. Once the pilot sample is selected from a larger population of applicants, using the same selection measures to then predict performance results in restricted range in the predictor variables. This, along with the use of pass/fail criterion further obscures potential individual difference, performance relationships. Putting together the restricted range in the pass/fail training criteria and the restricted range in the individual difference variables makes predictability unlikely.

The present study did not use the pass/fail or training grades as criteria, thereby attempting to avoid one of the prevailing criticisms of past research. Nor did the present study use flight school selection measures as predictors of performance in flight training. In this study, personality and attitude dimensions had not been

previously assessed for selection purposes. These dimensions are not used to set cut scores for admission to flight training. Thus, restricted range should not have occurred in the predictor measures (except cognitive ability). Recognizing that these cautions were noted and in light of the non significant results, the distribution of scores on the individual difference measures (excluding cognitive measures) in this study were compared to distributions used in other aviation research (Helmreich's research at UT/NASA, a data base used for many studies, reports, and publications). The distributions are very similar. Therefore, it can be concluded that the non-significant regressions between individual differences and cognitive processes and ultimately pilot error found in this study are not due to differences in populations. Therefore, the lack of significant relationships between the individual difference and criterion variables is either (1) true, individual differences do not influence cognitive style and ultimately pilot error behavior in the student pilot population or (2) that this research was unable to overcome factors that have plagued other efforts that have attempted to predict aspects of pilot training performance. Possible troublesome factors include rater bias, subject reactivity, and criterion contamination.

Each is a concern in this study. Even with the highly trained evaluation pilots, halo rating error and criterion contamination can occur. Halo could result from the evaluation pilot not noticing as many errors for those students they have already positively viewed. The criterion could be contaminated in that the rating pilot is not able to distinguish error behavior from non-error behavior. Subject reactivity is always a concern with overt observation. The results of this study do not clarify the extent each of these factors impacted the outcome of this research.

Unlike the personality and attitude differences, the cognitive ability measures employed in this study do appear to have a restricted range. This is not easily corrected, as the pilot selection system chooses candidates high in cognitive ability. This study was not able to uncover the relationship between cognitive ability and cognitive processes and pilot error. As long as research continues to use actual pilots in research efforts, this troubling fact may continue. Perhaps, future research designs should consider a population with a fuller range of cognitive scores on which to do preliminary studies. Computer or simulator research could be designed to address this issue.

It should be noted that, despite restricted range, in this study, cognitive ability did correlate with pilot error (Appendix D). This relationship should be explored in future studies and was not specifically addressed here, as it was not part of the proposed model that this study was designed to test.

An additional concern in this study is the use of the forced choice format Hazardous Thought Pattern scale. This study employed this measure because it had been developed from careful task analysis and subject matter expert judgement, resulting in valid content but highly questionable format. Recognizing the shortcomings of forced choice format, this study attempted to redesign the instrument avoiding the force choice format, without success. Since the concept on Hazardous Thought Patterns is so prevalent in the aviation community, and lacking a better assessment tool, the instrument was employed in its original form. Thus, results should be interpreted noting Anastasi's (1982) warning:

> It is important to bear in mind that in ipsative scores (resulting from forced choice format) the strength of each need is expressed, not in absolute terms, but in relation to the strength of the individual's other needs. The frame of reference in ipsative scoring is the individual rather than the normative sample. Because the individual responds by expressing a preference for one item against another, the resulting score is ipsative. Under these conditions, two individuals with identical scores may

> differ markedly in the absolute strength of their needs. (p. 517)

Anastasi further claims that interpretation of these scores is somewhat confusing and less consistent than with normative scores. In view of the popularity that the concept of pilot hazardous thought patterns, or hazardous cognitive styles enjoys and the widely hypothesized links to pilot error, it is necessary that future research concentrate on designing an assessment instrument for this concept in a form other than forced choice. When this psychometric roadblock has been passed, it may be possible to learn what influence, if any, does pilot cognitive style have on pilot error behavior.

Post hoc analysis of pilot error accident involvement related to individual differences have been largely unsuccessful (cited earlier in this paper). Being aware of these past failures, the present study evaluated pilot error involvement where and when it was happening. Assessing cockpit error in the individual pilot as a means of determining the effects of individual differences had not been previously attempted.

Noting all of the above cautions, the methodology employed in the present study had the potential to overcome restricted range confounds and the potential to uncover the relationship between individual differences

and cockpit error in real time rather that post hoc accident analysis. However, even with these important methodological considerations addressed, the present study carried its own set of limitations, which have been implied or directly addressed above. The most serious was the presence of the evaluation pilot as the rater. This presence could be intrusive, and the subjects could react to it. In this case it was felt that the impact of the rater observer may be minimized because the criterion behavior selected is not easily altered. It should be quite difficult for a student pilot to alter attention/perception and judgement/decision making. In fact, these errors did occur. But, there is no way of determining the true impact of the observer rater. The overt observation could influence pilot performance either by increasing stress level and thereby increasing error (as this data demonstrated) or by influencing the pilot to be more vigilant and thereby decreasing pilot error. The data cannot explicate which, if any of these influences, were operating in this pilot population.

Another limitation of this study, again, concerns the rating scale technique. Rater bias was discussed when psychological stress and performance was considered earlier in this discussion section. Overall, this methodology does not allow fine discrimination of the

criterion or the intervening variables. This study was limited to using the standard check ride grading sheet (basically a rating sheet) for evaluation set by the United States Army Aviation Training Division. A substantially more rigorous technique would have been to be able to employ simulator research with a computer form of error tabulation, thus removing the evaluation pilot from interpreting, and assessing error type and frequency. This technology was not available.

Helmreich et al. (1986) claim that research efforts to establish relationships between individual difference measures (specifically personality dimensions) and performance parameters are plagued by what is termed "the honeymoon effect." Helmreich has concluded that individuals in a training situation or when new to a job are likely to exert maximum effort, and this maximum effort may wash out the true relationship between personality and performance. However, Helmreich states, it is unlikely that individuals are able to sustain this type of performance over time. Thus, the true relationship between personality and performance may not be apparent until some time on the job has occurred.

Adherents to this philosophy would say that a possible reason that this present study did not expose significant relationships between individual differences and pilot

error is due to this honeymoon effect. The student pilots are new to the job and still in the training environment. This present data will be retained by the United States Army Research Institute with plans for longitudinal examination of accident/incident involvement for this student population. This longitudinal research may reveal the influence of individual differences and pilot error in subsequent line performance that were not apparent during pilot training and evaluation.

In summary, this study found that pilot situational awareness and pilot psychological stress levels do predict the frequency of attention/perception and judgement/ decision pilot cockpit error. However, it was not established that individual difference variables (personality, individual attitudes, or cognitive ability) affected either the development of situational awareness or the display of psychological stress. Nor did the individual difference variables contribute substantially to hazardous cognitive styles, and the hazardous cognitive styles were not related to pilot error in this study.

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APPENDIX A

TIME LINE AND RESEARCH PROCEDURES

TIME LINE

1st WEEK OF FLIGHT TRAINING

INDIVIDUAL DIFFERENCE MEASURES

1. The Helmreich Battery (4 subscales)

(a) Work and Family Orientation

The WOFO operationalizes achievement motivation as three distinct but correlated components defined as: Mastery Needs, Work orientation, and Competitiveness.

(b) Revised Jenkins Activity Survey

The revised JAS consists of two moderately correlated scales that have been labeled Achievement Striving and Impatience/Irritability. Achievement striving appears to capture a more driven aspect of the motives to achieve than the three components of the WOFO with which it is positively correlated. Impatience/irritability is a representation of a high sense of time urgency and a proneness to react to even minor frustrations with expressed irritation.

(c) Extended Personality Survey Questionnaire

The EPAQ measures positive and negative constellations of instrumental and expressive traits. EPAQ correlates (positively) with a variety of criteria of adjustment

including self-esteem and life satisfaction and negatively with seeking psychological counseling and neurotic acting out behaviors.

(d) Cockpit Management Attitude Questionnaire

The CMA assesses attitudes about personal reactions, decision making under stressful conditions, crew responsibilities, interpersonal communication and training (Test descriptions from Helmreich, 1988).

2. The Complex Cognitive Abilities Battery

The CCAB assesses the following cognitive abilities:

Responding to Data

This is composed of four complex cognitive capabilities or functions which can be characterized as a response to exogenous data (Attention to detail, Perception of form, Memory retrieval, and Time sharing).

Going Beyond Data

This category of cognitive demand is composed of four complex cognitive capabilities of functions, all of which can be characterized as *going* beyond data. These functions all require a person to perform endogenous cognitive operations on exogenous data. (Comprehension, Concept formation, Verbal reasoning, Quantitative analysis.)

Taking action based on data

This category of cognitive demand is composed of three complex cognitive capabilities or functions, all of which involve taking action. This category builds upon the second one in that the endogenous cognitive operations on the data are geared for taking action. (Planning, Situation assessment, Decision Making.)

Creating Data

This category of cognitive demand is composed of three complex cognitive capabilities, all of which can be characterized as creating data or creating solutions. The data created serves as input for the functions in the first three categories. (Communication, Problem Solving, Creativity.)

3. Eysenck Extroversion-Introversion Scale (3 subscales)

   (a) Introversion/extroversion

   (b) Neuroticism

   (c) Lie scale

4. Social Maladjustment Scale (1 scale)

Assesses the behavioral constellation: self-centeredness, overconfidence, aggressive attitudes, irresponsibility, resentfulness, intolerance, impulsivity, antisocial attitudes, and antagonistic attitude toward authority.

MEDIATING VARIABLE MEASURES

1. Hazardous Thought Pattern Scale (5 scales; 4 of which are independent)

The HTP measures the tendency towards the following cognitive patterns: Invulnerability, Impulsivity, Macho, Anti-Authority, Resignation.

The following mediating variable data was collected at the end of the basic contact phase of flight training and at the end of the advanced instrument phase of flight training at the same time that criterion error data was collected:

2. Pilot Situational Awareness Scale

3. Pilot Psychological Stress Level Scale

UPON COMPLETION OF BASIC CONTACT FLIGHT TRAINING AND AT THE END OF ADVANCED INSTRUMENT FLIGHT TRAINING. Data was collected in the same manner both times.

DATA COLLECTION

Criterion data and mediating variable data was collected at these two times.

EVALUATION PILOT

CRITERION COLLECTION

1. Data Collection of student pilot cockpit error type and error frequency during the helicopter check ride using the standard grading sheet provided by the flight training center.
2. Overall student pilot error type and frequency (for the two basic error types) recorded by the evaluation pilot on the rating scale developed for this research.

MEDIATING VARIABLE DATA COLLECTION

3. Student pilot situational awareness scale was filled out by the evaluation pilot.
4. Student pilot psychological stress level scale filled out by the evaluation pilot.

INSTRUCTOR PILOT

CRITERION DATA COLLECTION

1. Student pilot's expected performance recorded on the standard grading sheet provided by the flight training center.

APPENDIX B

ASSESSMENT BATTERY AND CRITERION DATA

COLLECTION INSTRUMENTS

ASSESSMENT TOOLS

INDIVIDUAL DIFFERENCES INSTRUMENTS

The Helmreich Battery consists of scales which measure:

1. Attitudes towards accomplishment
2. Self-esteem
3. Life-Satisfaction
4. Achievement motivation
   - Mastery needs
   - Satisfaction with hard work and task completion
   - Competitiveness
   - Concern for outperforming others in interpersonal situations
5. Achievement Striving--motivation for attainment goal orientation
6. Interpersonal Capacities
   - Assesses autocratic, dictatorial orientation
   - Empathy
   - Verbal Aggression
   - Passivity

7. Impatience and Irritability

A high sense of time urgency and proneness to react to even minor frustrations with expressed frustration

Helmreich Battery

(Aviator Motivational/Attitudinal Battery)

The items below inquire about what kind of a person you think you are. Each item consists of a **pair** of characteristics, with the letters A-E in between. For example:

Not at all artistic Very artistic

A.....B.....C....D.....E

Each pair describes contradictory characteristics--that is, you cannot be both at the same time, such as very artistic and not at all artistic.

The letters form a scale between the two extremes. You are to choose a letter which describes where <u>you</u> fall on the scale. For example, if you think you have no artistic ability, you would choose A. If you think you are pretty good, you might choose D. If you are only medium, you might choose C, and so forth.

Be sure to answer <u>every</u> question, even if you are not sure.

1. Not at all aggressive Very aggressive

A.....B.....C.....D.....E

2.	Very whiny	Not at all whiny
	A.....B.....C.....D.....E	
3.	Not at all independent	Very independent
	A.....B.....C.....D.....E	
4.	Not at all arrogant	Very arrogant
	A.....B.....C.....D.....E	
5.	Not at all emotional	Very emotional
	A.....B.....C.....D.....E	
6.	Very submissive	Very dominant
	A.....B.....C.....D.....E	
7.	Very boastful	Not at all boastful
	A.....B.....C.....D.....E	
8.	Not at all excitable in a major crisis	Very excitable in a major crisis
	A.....B.....C.....D.....E	
9.	Very passive	Very active
	A.....B.....C.....D.....E	
10.	Not at all egotistical	Very egotistical
	A.....B.....C.....D.....E	
11.	Not at all able to devote self completely to others	Able to devote self completely to others
	A.....B.....C.....D.....E	

12. Not at all spineless — Very spineless

A.....B.....C.....D....E

13. Very rough — Very Gentle

A.....B.....C.....D.....E

14. Not at all complaining — Very complaining

A.....B.....C.....D.....E

15. Not at all helpful to others — Very helpful to others

A.....B.....C.....D.....E

16. Not at all competitive — Very competitive

A.....B.....C.....D.....E

17. Subordinates self to others — Never subordinates to others

A.....B.....C.....D.....E

18. Very home oriented — Very worldly

A.....B.....C.....D.....E

19. Very greedy — Not at all greedy

A....B.....C.....D.....E

20. Not at all kind — Very kind

A.....B.....C.....D.....E

21. Indifferent to other's approval — Highly needful of other's approval

A.....B.....C.....D.....E

22. Very dictatorial — Not at all dictatorial

A.....B.....C.....D.....E

23. Feeling not easily hurt — Feelings easily hurt

A.....B.....C.....D.....E

24. Doesn't nag — Nags a lot

A.....B......C.....D.....E

25. Not aware of others feelings — Very aware of others feelings

A.....B.....C.....D.....E

26. Can make decisions easily — Have difficulty making decisions

A.....B.....C.....D.....E

27. Very fussy — Not at all fussy

A.....B.....C.....D.....E

28. Give up very easily — Never gives up easily

A.....B.....C.....D.....E

29. Very cynical — Not at all cynical

A.....B.....C.....D.....E

30. Never cries — Cries very easily

A.....B.....C.....D.....E

31.	Not at all self-confident	Very self-confident
	A.....B.....C.....D.....E	
32.	Does not look out only for self; principled	Look out only for self; unprincipled
	A.....B.....C.....D.....E	
33.	Feels very inferior	Feels very superior
	A.....B.....C.....D.....E	
34.	Not at all hostile	Very hostile
	A.....B.....C.....D.....E	
35.	Not at all understanding of others	Very understanding of others
	A.....B.....C.....D.....E	
36.	Very cold in relations relations with others	Very warm in with others
	A.....B.....C.....D.....E	
37.	Very servile	Not at all servile
	A.....B.....C.....D.....E	
38.	Very little need for security	Very strong need for security
	A.....B.....C.....D.....E	
39.	Not at all gullible	Very gullible
	A.....B.....C.....D.....E	

40. Goes to pieces under pressure — Stands up well under pressure

A.....B.....C.....D.....E

PART 2

For each question below, please select the alternative that best describes yourself or your opinion. Indicate the alternative you choose by circling the appropriate letter of the scale, A, B, C, D, or E.

41. How much does your job "stir you into action"

--A------B------C------D------E--

Much less than others	About average	Much more often than others

42. When a person is talking and takes too long to come to the point, how often do you feel like hurrying the person along?

--A---------B--------C--------D--------E

Very frequently	Occasionally	Almost never

43. Do you consider yourself to be:

--A--------B--------C--------D--------E

Very hard driving	Slightly hard driving	Very relaxed and easy-going

44. How would your best friend or others who know you well rate your general level of activity?

--A-----------B----------C----------D----------E

Too slow, should be more active	About average	Very active should slow down

45. Typically, how easily do you get irritated?

--A----------B----------C----------D-----------E

Extremely easily	Somewhat easily	Not at all easily

46. How seriously do you take your work?

--A--------B--------C--------D---------E

Much less seriously than most	About average	Much more than most

47. How often do you set deadlines or quotas for yourself at work or other activities?

--A----------B-----------C-----------D------------E--

Very often Sometimes Almost never

48. Do you tend to do most things in a hurry?

--A----------B------------C----------D--------E--

Not at all true More true then not Not true

49. Compared with others in my occupation, the amount of effort I put forth is:

--A--------B--------C--------D--------E--

Much more About average Much less

50.How is your "temper" these days?

--A--------B--------C--------D--------E--

Very hard to control About average I seldom get angry

51. Compared with others in my occupation, I approach life in general:

--A---------B---------C----------D-------E--

Much more seriously About average Much less seriously

52. When you have to wait in line such as at a restaurant, the movies, or the post office, how do you usually feel?

--A-------------B------------C-----------D----------E--

Accept it calmly Feel very impatient and refuse to stay long

PART 3

The following statements describe reactions to conditions of work and challenging situations. For each item, indicate how much you agree or disagree with the statement, as it refers to yourself, by choosing the appropriate letter on the scale, A, B, C, D, or E. When you have decided on your answer, circle the letter that best describes your attitude. There are no right or wrong answers.

53. I would rather do something at which I feel confident and relaxed than something which is challenging and difficult.

--A---------B-----------C------------D------------E--

Strongly agree	Neither agree or disagree	Strongly disagree

54. It is important for me to do my wok as well as I can even if it isn't popular with my co-workers.

--A-----------B------------C-------------D-----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

55. I enjoy working in situations involving competition with others.

--A-----------B---------------C----------D----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

56. When a group I belong to plans an activity, I would rather direct it myself than just help out and have someone else organize it.

--A-----------B-----------C-----------D-----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

57. I would rather learn easy fun games than difficult games.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

58. It is important to me to perform better than others on a task.

--A------------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

59. I find satisfaction in working as well as I can.

--A----------B-------------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

60. If I am not good at something I would rather keep struggling to master it than move on to something I may be good at.

--A----------B------------C------------D------------E--

Strongly agree | Neither agree or disagree | Strongly disagree

61. Once I undertake a task, I persist.

--A----------B------------C------------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

62. I prefer to work in situations that require a high level of skill.

--A-----------B------------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

63. There is a satisfaction in a job well done.

--A-------------B------------C------------D------------E--

Strongly agree | Neither agree or disagree | Strongly disagree

64. I feel that winning is important in both work and games.

--A------------B------------C------------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

65. I more often attempt tasks that I am not sure I can do than tasks that I believe I can do.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

66. I find satisfaction in exceeding my previous performance even if I don't outperform others.

--A------------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

67. I like to work hard.

--A------------B------------C------------D------------E--

Strongly agree | Neither agree or disagree | Strongly disagree

68. Part of my enjoyment in doing things is improving my past performance.

--A-------------B-------------C-------------D---------E--

Strongly agree | Neither agree or disagree | Strongly disagree

69. It annoys me when other people perform better than I do.

--A-------------B-------------C------------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

70. I like to be busy all the time.

--A--------------B---------------C-------------D--------E--

Strongly agree Neither agree or disagree Strongly disagree

71. I try harder when I'm in competition with other people.

--A-----------B------------C------------D---------E--

Strongly agree Neither agree or disagree Strongly disagree

72. It is important to me that my job offer opportunity for promotion and advancement.

--A------------B-----------C-------------D------------E--

Strongly agree Neither agree or disagree Strongly disagree

73. It is important to my future satisfaction that my job pay well.

--A-----------B------------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

74. It is important to me that my job bring me prestige and recognition from others.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

PART 4

As in the previous section, the following statements describe reactions to conditions of work. However, these statements are specifically oriented toward aircraft operations. For each item indicate how much you agree or disagree with the statement by choosing the appropriate letter on the scale. Again, there are no right or wrong answers.

75. Good working relations with all other crew members are essential to effective cockpit management.

--A----------B-----------C-----------D-----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

76. Pilots should feel obligated to mention their own psychological stress or physical problems to other flight crew personnel before or during a flight.

--A-----------B------------C-----------D----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

77. It is important to avoid negative comments about the procedures and techniques of other crew members.

--A-----------B-----------C-----------D-----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

78. Pilots in command should not dictate flight procedures to their copilots.

--A-----------B-----------C-----------D-----------E--

Strongly agree	Neither agree or disagree	Strongly disagree

79. Casual conversation in the cockpit during periods of low workload can improve crew performance.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

80. Each pilot should monitor other crew members for signs of stress or fatigue and should discuss the situation with the crew members.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

81. Instructions to other crew members should be general and nonspecific so that each individual can practice self-management and develop individual skills.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

82. Pilots should be aware of and sensitive to the personal problems of fellow crew members.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

83. The pilot in command should take the controls and fly the aircraft in emergency and nonstandard situations.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

84. The pilot flying the aircraft should verbalize his plans for maneuvers and should be sure that the information is understood and acknowledged by the other pilot.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

85. Copilots should not question the decisions or actions of the pilot in command except when they threaten the safety of the flight.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

86. The pilot in command should provide clear, direct orders concerning procedures to be followed in all situations.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

87. During periods of high workload, conversation in the cockpit should be kept to a minimum except for necessary operational matters.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

88. Pilots in command should encourage their copilots to question procedures during normal flight operations and in emergencies.

--A-----------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

89. There are no circumstances (except for total incapacitation) where the copilot should assume command/control of the aircraft.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

90. A debriefing and critique of procedures after each flight is an important part of effective cockpit management.

--A-----------B-----------C------------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

91. My performance is not adversely affected by having inexperienced or less capable crew members onboard.

--A------------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

92. Overall, successful cockpit management is primarily a function of the flying proficiency of the pilot in command.

--A-----------B-----------C-----------D-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

93. Training is one of the most important responsibilities of the pilot in command.

--A-----------B-----------C-----------d-----------E--

Strongly agree | Neither agree or disagree | Strongly disagree

94. A comfortable atmosphere is essential to maintaining a cooperative and harmonious cockpit.

--A------------B-----------C-----------D---------E--

Strongly agree | Neither agree or disagree | Strongly disagree

95. The pre-flight crew briefing is important for safety and effective crew management.

--A-----------B------------C------------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

96. Pilots in command should employ the same style of management in all situations and with all crew members.

--A-----------B----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

97. The responsibilities of the pilot in command include coordination of cockpit crew activities.

--A----------B-----------C-------------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

98. An effective pilot can leave behind personal problems when flying.

--A-----------B------------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

99. My decision making ability is as good in emergencies as in routine flying situations.

--A------------B-----------C-----------D-----------E--

Strongly agree Neither agree or disagree Strongly disagree

Eysenck Personality Inventory

"The Eysenck Personality Inventory measures personality in terms of two pervasive, independent dimensions. These dimensions are identified as extraversion-introversion and neuroticism-stability. Each of these traits is measured by means of 24 questions, selected on the basis of item and factor analyses, to which the examinee answers "yes or "no". A distortion scale is also included to detect attempts to falsify responses." (EPI Manual)

Instructions

Here are some questions regarding the way you behave, feel, and act. After each question is a space for answering "Yes", or "No".

Try and decide whether "Yes" or "No" represents your usual way of acting or feeling. Then blacken in the space under the columns headed "Yes" or "No".

Work quickly and do not spend too much time over any question; we want your fist reaction, not a long drawn-out thought process. The whole questionnaire should not take more than a few minutes. Be sure not to omit any questions. Work quickly, and remember there are no right or wrong answers and this is not a test of intelligence or ability, but simply a measure of the way you behave.

1. Do you often long for excitement?
2. Do you often need understanding friends to cheer you up?
3. Are you usually carefree?
4. Do you find it very hard to take no for an answer?
5. Do you stop and think things over before doing anything?...yes or no

6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be do to so?...yes or no
7. Does your mood often go up and down?
8. Do you generally do and say things quickly without stopping to think?
9. Do you ever feel "just miserable" for no good reason?
10. Would you do almost anything for a dare?
11. Do suddenly feel shy when you want to talk to an attractive stranger?
12. Once in a while do you lose your temper and get angry?
13. Do you often do things on the spur of the moment?
14. Do you often worry about things you should not have done or said?
15. Generally do you prefer reading to meeting people?
16. Are your feelings rather easily hurt?
17. Do you like going out a lot?
18. Do you occasionally have thoughts and ideas that you would not like other people to know about?
19. Are you sometimes bubbling over with energy and sometimes very sluggish?
20. Do you prefer to have few but special friends?
21. Do you daydream a lot?
22. When people shout at you, do you shout back?
23. Are you often troubled about feelings of guilt?
24. Are all your habits good and desirable ones?
25. Can you usually let yourself go and enjoy yourself a lot at a lively party?
26. Would you call yourself tense or "highly-strung"?
27. Do other people think of you as being very lively?
28. After you have done something important, do you often come away feeling you could have done better?

29. Are you mostly quiet when you are with other people?
30. Do you sometimes gossip?
31. Do ideas run through your head so that you cannot sleep?
32. If there is something you want to know about, would you rather look it up in a book than talk to someone about it?
33. Do you get palpitations of thumping in your heart?
34. Do you like the kind of work that you need to pay close attention to?
35. Do you get attacks of shaking or trembling?
36. Would you always declare everything at the customs, even if you knew that you could never be found out?
37. Do you hate being with a crowd who play jokes on one another?
38. Are you an irritable person?
39. Do you like doing things in which you have to act quickly?
40. Do you worry about awful things that might happen?
41. Are you slow and unhurried in the way you move?
42. Have you ever been late for an appointment or work?
43. Do you have nightmares?
44. Do you like talking to people so much that you would never miss a chance of talking to a stranger?
45. Are you troubled by aches and pains?
46. Would you be very unhappy if you could not see lots of people most of the time?
47. Would you call yourself a nervous person?
48. Of all the people you know are there some whom you definitely do not like?
49. Would you say you were fairly self-confident?
50. Are you easily hurt when people find fault with you or your work?
51. Do you find it hard to really enjoy yourself at a lively party?
52. Are you troubled with feelings of inferiority?

53. Can you easily get some like into a rather dull party?

54. Do you sometimes talk about things you know nothing about?

55. Do you worry about your health?

56. Do you like playing pranks on others?

57. Do suffer from sleeplessness?

The extroversion-introversion scale items are #:

1;3;5;8;10;13;15;17;20;22;25;27;29;32;34;37;39;41;44;46;49;51;
53;56.

The Neurotic scale items are #:

2;4;7;9;11;14;16;19;21;23;26;28;31;33;35;38;40;43;45;47;50;52;
55;57.

The Lie scale items are #:6;12;18;24;30;36;42;48;54.

General Social Maladjustment Scale

The General Social Maladjustment Scale (Hansen, 1989) derived from the MMPI measures:

1. Self-centeredness
2. Over confidence
3. Aggression
4. Irresponsibility
5. Resentment
6. Intolerance
7. Impulsivity
8. Anti-Social Attitudes
9. Antagonistic towards authority

Answer True or False.

1. When someone does me a wrong I feel I should pay him back if I can, just for the principle of the thing.
2. During one period when I was a youngster I engaged in petty thievery.
3. At times I feel like smashing things.
4. As a youngster I was suspended from school one or more times for cutting up.
5. I have often had to take orders from someone who did not know as much as I did.
6. I think most people would lie to get ahead.
7. I commonly wonder what hidden reason another person may have for doing something nice for me.
8. At times I feel like picking a fistfight with someone.
9. I have the wanderlust and am never happy unless I am roaming or traveling about.

10. I have used alcohol excessively.

11. My way of doing things is apt to be misunderstood by others.

12. I have never been in trouble with the law.

13. If several people find themselves in trouble, the best thing for them to do is to agree on a story and stick to it.

14. I enjoy the excitement of a crowd.

15. I am often said to be hotheaded.

16. I am not easily angered.

MEDIATING VARIABLE INSTRUMENTS

The Hazardous Thought Pattern Scale measures:

1. Anti-authority
2. Impulsivity
3. Invulnerability
4. Macho
5. External control--resignation

The measure to be used was designed by the FAA and used in subsequent research by Lester and Bombasi (1984); Lester and Connally (1987).

Hazardous Thought Patterns Assessment Inventory (to be reproduced without the name). THIS VERSION OF THE SCALE DIFFERS FROM THAT IN THE ORIGINAL PROPOSAL, SINCE THE ORIGINAL MET WITH RESISTANCE FROM THE STUDENT PILOTS. THIS IS AN ATTEMPT TO REDUCE NEGATIVE RESPONSES FROM THE TEST TAKERS.

In this section of the questionnaire, you will be presented with ten flight situations. These are troublesome situations in which a pilot may find him/herself. In each situation a decision has been made regarding the flight. Read each situation and the reasons for the decision that follow. Then decide which of reasons would be most acceptable to you and which of the reasons would be least acceptable to you in the same situation. Place an "M" in the box next to the most acceptable reason and a "L" in the box next to the least acceptable reason for the decision.

Situation 1

You are on a flight to a unfamiliar, rural construction site. Flight service (where you file flight plans and receive weather information), states that Visual Flight Rules is not recommended (thus you will be flying on instruments) since heavy coastal fog is forecast to move into the destination area about the time you expect to land. You first consider returning to your home base where visibility is still good but decide instead to continue as planned and land safely after some problems. Why did you reach this decision?

--------a. You hate to admit that you cannot complete your original flight plan.

--------b. You resent the suggestion by flight service that you should change your mind.

--------c. You feel sure that things will turn out safely, that there is no danger.

________d. You reason that since your actions would make no real difference, you might as well continue.

________e. You feel the need to decide quickly so you take the simplest alternative.

Was the pilot's conduct

1............2............3............4............5

Very much like me   Not at all like me

Situation 2

On takeoff you notice an unusual stiffness in the aircraft controls (which may signal a potentially dangerous situation). Once airborne, you are sufficiently concerned about the problem to radio for information. Since strong winds are reported at your destination,

an experienced pilot who is a passenger recommends that you abandon the flight and return to your departure airport. You choose to continue the flight and experience no further difficulties. Why did you continue?

______a. You feel that suggestions made in this type of situation are usually overly cautious.

______b. Your flight controls have never failed before so you doubt that they will this time.

______c. You feel that you can leave the decision to the control tower at your destination. (They will close the airport if weather conditions are severe enough to endanger landings.)

______d. You immediately decide that you want to continue.

______e. You are sure that if anyone could handle the landing, you can.

Was the pilot's conduct

1............2............3............4.............5

Very much like me Not at all like me

Situation 3

The regular helicopter you fly has been grounded because of an airframe problem. You are scheduled in another helicopter and discover it is a model that you are not familiar with. After your preflight inspection, you decide to takeoff on your mission as planned. What was the your reasoning?

______a. You feel that a difficult situation will not arise so there is no reason not to go.

______b. You tell yourself that if there were any danger, you would not have been offered that helicopter model to fly.

______c. You are in a hurry and do not want to take the time to think of alternate choices.

______d. You do not want to admit that you may have trouble flying an unfamiliar helicopter.

______e. You are convinced that your flight instructor was much too conservative and pessimistic when he cautioned you to be thoroughly familiar and experienced in each helicopter that you fly.

Was the pilot's conduct

1...........2............3............4............5

Very much like me   Not at all like me

Situation 4

You were briefed before the flight about possible icing conditions occurring during the flight (which may adversely affect the safety of the flight) but did not think there would be any problem since your heliport surface temperature was 60° F. As you near your destination, you encounter freezing rain, which clings to your windshield. Your passenger, who is a more experienced pilot, begins to panic. You consider turning back to the original heliport but continue instead. Why did you not return? Why did he/she not return?

_____a. You feel that having come this far, things are out of your hands.

_____b. The panic of the passenger makes you "commit yourself" without thinking the situation over.

_____c. You do not want the passenger to think you are afraid.

_____d. You are determined not to let the passenger think he can influence what you do.

_____e. You do not believe that the icing could cause your helicopter to crash in these circumstances.

Was the pilot's conduct

1...........2............3............4............5

Very much like me   Not at all like me

Situation 5

You do not bother to check weather conditions at your destination. En route, you encounter headwinds, which slows down the aircraft. Your fuel supply is adequate to reach your destination, but there is almost no reserve for emergencies. You continue the flight and land with a nearly dry tank. What most influenced you to do this?

_____a. Being unhappy with the pressure of having to choose what to do, you make a snap decision.

_____b. You do not want your friends to hear that you had to turn back.

_____c. You feel that operator manuals always understate the safety margin in fuel tank capacity.

_____d. You believe that all things usually turn out well, and this will be no exception.

_____e. You reason that the situation has already been determined because the destination is closer than any other heliport.

Was the pilot's conduct

1...........2............3............4............5

Very much like me   Not at all like me

Situation 6

You are forty minutes late for take off in a helicopter, and since you experienced no problems with this same helicopter on the previous day's flight, you decide to skip most of the preflight check. What leads you to this decision?

_____a. You simply take the first idea to making up time that came to mind.

_____b. You feel that your reputation for being on time demands that you cut corners when necessary.

_____c. You believe that some of the required preflight inspection is just a waste of time.

_____d. You see no reason to think that something unfortunate will happen during this flight.

_____e. If any problems develop, the responsibility would not be yours. It is the maintenance of the helicopter that really makes the difference.

Was the pilot's conduct

1............2............3............4............5

Very much like me Not at all like me

Situation 7

You are to fly a helicopter which you know is old and has been poorly maintained. A higher than normal engine system temperature on start up is indicated, and you suspect the fuel system to be defective. Two fellow company pilots, who are traveling as passengers, do not want to be delayed. After five minutes of debate, you agree to make the trip. Why did you permit yourself to be persuaded?

_____a. You feel that you must always prove your ability as a pilot, even under less than ideal circumstances.

_____b. You believe that regulations overstress safety in this kind of situation.

_____c. You think that the fuel control system will certainly last for just one more flight.

_____d. You feel that your opinion may be wrong since the two other pilots are willing to take the risk.

_____e. The thought of changing arrangements is too annoying, so you jump at the suggestion of the other pilots.

Was the pilot's conduct

1.................2.............3...........4............5

Very much like me Not at all like me

Situation 8

You are in the final phase of the flight and are getting ready to land when you notice a large unidentified object on the far side of the landing site. You consider going around (abandoning your landing approach), but your co-pilot suggests landing anyway since the Landing Zone is "obviously large enough to handle both the obstacle and your helicopter." You land with your rotor blades very, very close to the obstacle. Why did you agree to land?

_____a. You have never had an accident, so you feel that nothing will happen this time.

_____b. You are pleased to have someone else help with the decision and decide your co-pilot is right.

_____c. You do not have much time, so you just go ahead and act on your co-pilot's suggestion.

_____d. You want to show your co-pilot that you can control the helicopter precisely.

_____e. You feel that the regulations making the pilot responsible for the safe operation of the helicopter do not apply here since it is the ground crews responsibility to assure sufficient landing area.

Was the pilot's conduct

1................2............3...........4............5

Very much like me Not at all like me

Situation 9

You are preparing to land in an unimproved Landing Zone (rough terrain which makes landing more risky than normal). In addition, as you get closer, you see that the wind has changed from what you had expected from earlier weather reports. The standard operating procedures for this situation (unimproved landing zone and cross winds) require that you to abandon your present landing approach, go around , and make another approach so that you are landing into the wind. Instead of doing the required procedures, which is time consuming, you make two abrupt turns to maneuver your aircraft into the wind for landing. What was your reasoning?

_____a. You believe you are a really good pilot who can safely make sudden maneuvers.

_____b. You believe your flight instructor (and standard operating procedure) was overly cautious when insisting that a pilot must go around rather than make sudden course changes while on final approach.

_____c. You know there would be no danger in making the sudden turns because you do things like this all the time.

_____d. You know landing into the wind is best, so you act as soon as you can to avoid a crosswind landing.

_____e. The unexpected wind change is a bad break, but you figure if the wind can change, so can you.

Was the pilot's conduct

1................2............3...........4............5

Very much like me Not at all like me

Situation 10

You have flown to your destination heliport only in daylight and believe that you know it well. You learn that your helicopter needs a minor repair which will delay your arrival until well after dark. Although a good portion of the flight is after dark, you feel that you should be able to recognize some of the lighted landmarks. Why did you decide to make the flight?

_____a. You believe that when your time comes you cannot escape, and until that time there is no need to worry.

_____b. You do not want to wait to study other alternatives, so you carry out your first plan.

_____c. You feel that if anyone can handle this problem, you can do it.

_____d. You believe that the repair is not necessary. You decide you will not let recommended but minor maintenance stop you from getting to your destination.

_____e. You simply do not believe that you could get off course despite your unfamiliarity with ground references at night.

Was the pilot's conduct

1.................2.............3...........4............5

Very much like me   Not at all like me

Situational Awareness

The situational awareness scale was constructed by the researcher according to tasks-conditions-standards established by the Aviation Training Center and subject matter expert opinion. The evaluation pilots will rate the student pilot's overall situational awareness during the flight immediately after the check rides.

Situational Awareness Assessment Scale (to appear as a BARS scale)
Please rate the student pilot on his/her "Situational Awareness" during the flight.

Situational Awareness can be thought of as the accurate perception of the factors and conditions affecting the flight crew and the aircraft.

High Anchor
The pilot knows precisely where the aircraft is at all times, and detects any change in the flight status immediately. The pilot is conscious of all parameters that affect the flight.

Low Anchor
Pilot is unaware of important factors that affect the safety of the flight and/or is overly concerned with one aspect of the flight and ignores other critical elements of safe flight.

Example of behavior for the High Anchor: The pilot is aware of altitude, location, airspeed, wind, weather, communications, etc. The pilot is equally attentive to all aspects of the flight.

Example of behavior for the Low Anchor: The pilot does not know where other aircraft are, miscalculates landing speed, misses radio calls, misses navigation checks, violates airspace clearance. Poor situational awareness may also result then the pilot is overly concerned with one aspect of the flight task and ignores others. The pilot, engrossed in instruments or concentrating on a basic maneuver, does not consider where the aircraft will end up.

Student pilot psychological stress level scale

This measure was developed by the researcher based on existing theory regarding psychological stress and pilot performance.

PILOT PSYCHOLOGICAL STRESS RATING SCALE

Please rate the student pilot's psychological stress level during the flight just completed. You may have sensed that the student was uncharacteristically "tense" during the flight. This tenseness is the outward signs of psychological stress. Please rate the level of "tenseness" or stress present. In doing so, consider the following observable or outward signs of stress:

Sweating

Trembling

A level of excitement (not appropriate for the situation)

Restlessness

Exaggerated startle reflex (Jumping at sudden noises)

Laughing loudly when not appropriate

Slowed speech

Rapid speech

Talking in incomplete sentences

Talking in sentences that do not make clear sense

During the flight the student may have displayed one or several of these outward signs of stress. This rating is asking for your impression of the student's overall level of stress; tension.

Student pilot psychological stress level scale

1	Very low; no outward signs of stress; no apparent tension
2	
3	Moderate level of stress displayed
4	
5	Very high stress level

CRITERION COLLECTION INSTRUMENTS

NOTES

The criterion in this study was the frequency and the type of error committed by individual student helicopter pilots during the check rides for the basic and advanced phase of instrument flight training. Evaluation pilots served as rating observers. The evaluation pilots rated each student pilot's performance on the essential flight tasks as well as overall performance for the aviation center as a pass/fail check ride, as is the standard operating procedure. The standard rating form used to evaluate student pilots reflects performance level on each task that is essential to successful and safe completion of the particular maneuver being assessed. Additionally, when a task was not completed "error free," the instructor pilot noted the reason for the error. This categorization scheme fits well with the conceptual model of pilot error that this research has proposed.

The specific check ride routings flown by each student pilot are standardized to the degree that there are essential tasks that the student pilot must successfully accomplish in order to achieve a passing grade for the ride. These tasks are clearly identified and described in detail in the instructor's manual.

The advanced instrument phase of pilot training was selected as the setting for this research on the basis that the student has already mastered basic flying tasks in earlier phases of training. Thus, this phase of training focuses on the mental skills required to fly a mission successfully. Since this research is not considering psychomotor error but concentrating on cognitive error, this segment of the training seems most appropriate. The Aviation center requested that data also be collected during the primary phase of flight

training. The center claims that most helicopter mishaps occur during close quarters, navigational exercises of which are stressed during primary flight training. Thus, this research will also collect error data during the primary phase of flight training, more as a service to our sponsor than as a critical aspect of this dissertation project.

DATA COLLECTION INSTRUMENTS

At the end of the basic instrument phase and at the end of the advanced instrument phase of pilot training, cockpit error frequency and error type (attentional/perception; judgmental/decisional) will be recorded by evaluation pilots during the helicopter check ride. The evaluation pilots will use the standard grading sheet provided by the evaluations and standardization branch of the flight training center to evaluate the students on these check rides. These check rides are standard operating procedure of the flight training center and were not initiated by this research project.

Also, at these check ride points (at the end of basic and the end of advanced instruments) the individual student's instructor pilot will record a student pilot expected performance for each helicopter check ride on the standard grading sheet that is also used for check rides. This is flight training standard operating procedures and not initiated by this research project. This student pilot performance (which includes error type and frequency) evaluation is based on the instructor's exposure to the trainee's simulator, flight, and classroom performance during either the basic or advanced instruments phases of flight training. The flight training center considers the average of these two (the actual check ride grade and the expected performance grade) evaluations as a more accurate estimate of the student's flying proficiency than either in isolation.

Upon completion of the check flights (one for basic instruments and one for advanced instruments) the evaluation pilot will rate: the frequency of the two basic error types of pilot error using a scale constructed by the researcher and subject matter experts.

Pilot Error will be assessed by instructor pilots using the standard rating sheet developed by the aviation training center, and the following rating scales constructed by the researcher. Evaluation pilots will be trained, by the researcher, to rate individual attention/perception errors and cognitive/decision errors that occur during the helicopter check rides. However, these evaluation pilots have been extensively trained in evaluation methods by the Aviation training center so will require only brief instruction and explanation of this particular rating scheme. Many of the instructor pilots that will be doing the rating have 1,500 hours of student pilot evaluation experience.

PILOT ERROR RATING SCALES

Please rate the frequency with which Attentional/Perception and Judgmental/Decisional errors were committed by the student pilot during the flight just completed.

A definition of each error type is provided as a general guideline. You may be familiar with these definitions as they are based, in part, on the Uniform Flight Grading System Regulations.

Examples of each error type are also provided. This list of examples DOES NOT include every error that may occur during flight. When you are rating the student please consider other errors that occurred during the flight that you feel fit the descriptions provided. Please have your rating reflect these errors as well as the few that are described above.

ATTENTION/PERCEPTION ERRORS

This category of error refers to the degree of vigilance that the student demonstrated during the flight. Vigilance is concerned with alertness and quickness in noticing the important factors of the flight environment. Totally missing objectively present information or missing parts of objectively present information are errors of attention/perception. Fixation on one segment of the flight task and ignoring other critical aspects of the flight task are also errors of attention/perception.

EXAMPLES:

Failed to check and maintain aircraft attitude

Failed to check and maintain altitude

Delayed in taking necessary actions

Poorly scanned instruments

Failed to check and maintain airspeed

Please rate the frequency with which the student pilot committed Attention/Perception type error on the following scale:

1 Did not commit this error

2 Seldom committed this error

3 Occasionally

4 Frequently

5 Very often

JUDGMENTAL/DECISIONAL ERRORS

This category of error refers to faulty information processing such as erroneous judgement, miscalculations, wrong decisions, and faulty action plans. Judgmental/decisional activity is concerned with how information is processed once it has been perceived. It is directed at the selection of methods to achieve objectives or goals according to the circumstances of a situation and past experience. This error type can also be conceptualized as "faulty headwork."

EXAMPLES:

Penetration into IMC under VFR

Misjudgments of weather conditions

Misjudging an approach path

Navigational error

Miscalculates fuel reserves or endurance

Please rate the frequency with which the student pilot committed Judgmental/Decisional type error on the following scale:

1 Did not commit this error

2 Seldom committed this error

3 Occasionally committed this error

4 Frequently

5 Very often

UNITED STATES ARMY AVIATION CENTER INSTRUMENTS

(Pilot Grading Slips)

STAGE TWO GRADESLIP

GROUND / IN-FLT PROCEDURES	A	B	C	U	NG
Rdo Improper	Cockpit Cks	Pre-Flt	Post-Flt		
	Radio Calls	Fuel Ck	Hover Ck		

TAKEOFF & LANDING TO HOVER	A	B	C	U	NG
Drifts	Aft	Fwd			

HOVERING FLIGHT	A	B	C	U	NG
Low	High	Slow	Fast		

NORMAL TAKEOFF	A	B	C	U	NG

NORMAL APPROACH	A	B	C	U	NG

TRAFFIC PATTERN	A	B	C	U	NG

SIM MAX PERFORMANCE T/O	A	B	C	U	NG
Before T/O Check	Pwr Ck	Improper			
Power Application	Slow	Abrupt			
A/C Attitude, Nose	Low	High			
Power, Too	Little	Much			
Return to Normal Climb, Slow	Fast	Early	Late		
Pedal, Too Much	Left	Right			
Ground Track, Drifts	Left	Right			

STEEP APPROACH TO GROUND	A	B	C	U	NG
Entry, Alignmt(L)(R)	A/S (-) (+)	Alt (-) (+)			
Sight Picture	Shallow	Steep			
Angle U/ARC, 1st, 2nd, All	O/ARC, 1st, 2nd, All				
Center Line	Left	Right			
Rate of Closure	Slow	Fast			
Pedal, Too Much	Left	Right			
Termination, Long	Short	Slide	Vert		

SLOPE OPERATIONS	A	B	C	U	NG
Landing: Cyclic, Uses Too	Little	Much			
Collective Reduction	Partial	Abrupt			
Pedal	U/CTL	O/CTL			
Drift, Left	Right	Forw.	Aft		
Takeoff: Cyclic, Uses Too	Little	Much			
Collective, Applies Too	Much	Abrupt			
Pedal	U/CTL	O/CTL			
Drift, Left	Right	Forw.	Aft		

POWER RECOVERY	A	B	C	U	NG
Throttle Application	Slow	Abrupt			
Climb Power	Little	Much			
Pedal, Too Much	Left	Right			
Climb Airspeed	Slow	Fast			
Clearing Turn	Insufficient	None			

HOVERING AUTOROTATION	A	B	C	U	NG
Entry Altitude	Low	High			
Entry Collective	Increase	Decrease			
Heading	Left	Right			
Pitch Pull	Low	Little	Much		
Touchdown	Hard	Tail Low	Nose Low		
Drifts	Aft	Fwd			

STANDARD AUTOROTATION	A	B	C	U	NG
Lane Alignment	Left	Right			
Reduce Collective	Slow	Fast			
Airspeed	Entry (-) (+)	Descent (-) (+)			
Callouts (RPM) (HI) (Trim)	Incomplete	None			
Decel	Low	High	Little	Much	
Initial	Low	High	Little	Much	
Cushion	Low	High	Little	Much	
Touchdown Zone	Short	Long			
Touchdown	Level	Toes	Hard		
Heading, Centerline	Left	Right			

AUTOROTATION WITH TURN	A	B	C	U	NG
Downwind	Close	Far			
Reduce Collective	Slow	Fast			
Pedal, Too Much	Left	Right			
A/C Attitude, Nose	Low	High			
Callouts (RPM) (HI) (Trim)	Incomplete	None			
Turn And Roll Out	U/Shot	O/Shot			
Airspeed at 100 Feet	Low	High			
Decel	Low	High	Little	Much	
Initial	Low	High	Little	Much	
Cushion	Low	High	Little	Much	
Touchdown Zone	Short	Long			
Touchdown	Level	Toes	Hard		
Heading, Centerline	Left	Right			

SIM ENGINE FAILURE AT ALT	A	B	C	U	NG
Reduce Collective	Slow	Fast	Partial		
Pedal, Too Much	Left	Right			
Descent Airspeed	Slow	Fast			
Callouts (RPM) (HI) (Trim)	Incomplete	None			
Area Selection	Adequate	Poor			
Accuracy	Short	Over			

BASIC QUALITIES	A	B	C	U
1 Flight Safety				
2 Retention of Instruction				
3 Aptitude				
4 Oral Knowledge				
5 Application of Procedures				
6 Alertness				
7 Division of Attention				
8 Control Touch				
9 Coordination				
10 Reaction Time				
11 Planning and Judgement				
12 Motivation				
13 Attitude				
14 Confidence				
15 Composure				

STUDENT'S LAST NAME, FIRST, M.I			RANK	CLASS	
INSTRUCTOR'S LAST NAME, FIRST, M.I			TRAINING DAY	DATE	JULIAN DATE
SUPR'S INITIALS	STUDENT'S INITIALS	FLT TIME	CUM TIME	OVERALL GRADE: A B C U	
GUEST IP:					STAC

LOW LEVEL AUTOROTATION	A	B	C	U	NG
Entry	Alt (-) (+)	A/S (-) (+)	Pwr (-) (+)		
Altitude During Decel	Gain	Lost			
Decel	Little	Much			
Initial	Low	High	Little	Much	
Cushion	Low	High	Little	Much	
Touchdown Zone	Short	Long			
Touchdown	Level	Toes	Hard		
Heading, Centerline	Left	Right			

HYDRAULICS OFF	A	B	C	U	NG			
Emergency Procedure	Improper	None						
Entry	Align(L)(R)	A/S (-) (+)	Alt (-) (+)					
Sight Picture	Shallow	Steep						
Angle	U/ARC	1st	2nd	All	O/ARC	1st	2nd	All
Rate of Closure	Slow	Fast						
Pedal, Too Much	Left	Right						
Cyclic / Collective	U/CTL	O/CTL						
Termination	Slow	Fast	Rough	Long				
Center Line, Touchdown	Left	Right						

FIXED PEDAL OPNS (L) (R)	A	B	C	U	NG
Entry	Pwr (-) (+)	A/S (-) (+)	Alt (-) (+)		
Angle	U/ARC	O/ARC	Shallow	Steep	
Rate of Closure	Slow	Fast			
Collective	U/CTL	O/CTL	Improper		
Throttle	U/CTL	O/CTL	Improper		
Cyclic	U/CTL	O/CTL	Improper		
Termination	Slow	Fast	Rough		
Centerline	Left	Right			
Nose at Touchdown	Left	Right			

SET AT A HOVER	A	B	C	U	NG
Cyclic	U/CTL	O/CTL			
Collective	Increase	Decrease			
Heading	Left	Right			
Pitch Pull	Low	Little	Much		
Touchdown	Hard	Tail Low	Nose Low		
Drift (L) (R)	Mod	Exc			

EMERGENCY GOVERNOR OPERATIONS	A	B	C	U	NG
Improper Procedure	Emer	Auto			
RPM	Low	High			
Pedal	U/CTL	O/CTL			
Altitude	Low	High			
Rate of Turn	Slow	Fast			
Drifts	Mod	Exc			

CONF. AREA / PINN. OPNS	A	B	C	U	NG
High Recon:	Close	Far	Incomplete		
A/C Control	Trvl(L)(R)	A/S (-) (+)	Alt (-) (+)		
Low Recon: Angle	Shallow	Steep			
Rate of Closure	Slow	Fast			
Barrier Clearance	Little	Much			
Termination	Short	Long			
Ground Recon: Procedure	Bar. Cl.	Wind			
A/C Control	Cyclic	Pedals	Alt(-)(+)		
Takeoff: Planning	Obst.	Flt Path			
Collective Application	Slow	Abrupt			
A/C Attitude, Nose	Low	High			
Pedal, Too	Little	Much			
Airspeed Increase	Slow	Fast	Early	Late	

COMMENTS:

THIS STATEMENT MUST BE COMPLETED IF PERFORMANCE IS UNSATISFACTORY

BEEN CRITIQUED AND UNDERSTAND WHY I RECEIVED THIS GRADE.
I (DO) (DO NOT) DESIRE A CHANGE OF INSTRUCTOR.

APPENDIX C

MISSING VALUES

VARIABLE	NUMBER OF VALID CASES	NUMBER OF MISSING CASES
Achievement Motivation	276	36
Vulnerability	312	00
Impatience	276	36
Cognitive Ability		
Extroversion	312	00
Social Maladjustment	312	00
Situational Awareness	265	47
Stress	267	45
Macho	312	00
Anti-Authority	312	00
Invulnerability	312	00
Impulsivity	312	00
Resignation	312	00
Attention Perception Error	297	15
Judgment Decision Error	297	15

The missing cases are due to procedural or clerical error and not systematically missing. The missing cases for the variables achievement motivation and impatience are clerical errors; Fort Rucker misplaced the scores for those scales for the subjects. The missing cases for the variables situational awareness and stress occurred because one class of student pilots took the checkride without the rating forms being distributed to the evaluation pilots. The missing values for the variables attention perception error and judgment decision error are due to the raters not filling out the rating form as instructed; thus the information was missing for those subjects.

APPENDIX D

NUMBER OF VALID OBSERVATIONS

(Number of Valid Observations Listwise = 231.00)

VARIABLE	MEAN	MINIMUM	MAXIMUM	STD. DEV.	VALID OBSERVATIONS	MISSING OBSERVATIONS
ATTPER	1.795	.67	3.00	.327	297	15
JUDDEC	1.706	.67	2,80	.359	297	15
SA	3.219	1.00	5.50	.848	265	47
STRESS	2.494	1.00	5.00	.869	267	45
MACHO	1.346	0	7	1.253	312	0
AUTHOR	1.234	0	5	1.128	312	0
RESIG	2.651	0	7	1.326	312	0
IMPUL	1.811	0	6	1.298	312	0
INVUL	2.763	0	7	1.588	312	0
TEXTRO	11.587	4	18	2.143	312	0
VULNER	2.648	.01	9.99	1.805	312	0
INST	46.595	11	65	6.330	274	38
TSM	7.183	2	16	2.366	312	0
COG	1090.919	715.40	5229.80	542.659	297	15
IMPATS	13.301	6	24	2.860	276	36

CORRELATION MATRIX FOR ALL MEASURES

	ATTPER	JUDDEC	SA	STRESS	MACHO	AUTHOR	RESIG	IMPUL	INVUL	TEXTRO	VULNER	INST	TSM	COG	IMPATS
ATTPER	1.0000 (297) p=.														
JUDDEC	.7560 (297) p=.000	1.0000 297 p=.													
SA	-.3756 (265) p=.000	-.3944 (265) p=.000	1.0000 (265) p=.												
STRESS	.3958 (287) p=.000	.4808 (287) p=.000	-.2497 (264) p=.000	1.0000 (287) p=.											
MACHO	.0169 (297) p=.386	.0078 (297) p=.448	-.0964 (265) p=.055	.0282 (287) p=.318	1.0000 (312) p=.										
AUTHOR	.0293 (297) p=.307	.0137 (297) p=.407	-.0418 (265) p=.249	.0617 (287) p=.157	-.0597 (312) p=.146	1.0000 (312) p=.									
RESIG	.0467 (297) p=.211	.0147 (297) p=.400	.1143 (265) p=.032	-.0843 (287) p=.085	-.2791 (312) p=.000	-.2439 (312) p=.000	1.0000 (312) p=.								
IMPUL	-.0140 (297) p=.405	-.0389 (297) p=.252	-.0354 (265) p=.283	-.0165 (287) p=.394	-.2128 (312) p=.000	-.1388 (312) p=.007	-.1188 (312) p=.018	1.0000 (312) p=.							
INVUL	-.0067 (297) p=.461	.0153 (297) p=.396	.0595 (265) p=.167	-.0183 (287) p=.383	-.2445 (312) p=.000	-.2632 (312) p=.000	-.2303 (312) p=.000	-.3479 (312) p=.000	1.0000 (312) p=.						

	ATTPER	JUDDEC	SA	STRESS	MACHO	AUTHOR	RESIG	IMPUL	INVUL	TEXTRO	VULNER	INST	TSM	COG	IMPATS
TEXTRO	-.0311 (297) p=.297	-.0188 (297) p=.373	-.0253 (265) p=.341	-.0231 (287) p=.354	.0918 (312) p=.053	-.0955 (312) p=.046	-.0657 (312) p=.124	.0470 (312) p=.204	.0514 (312) p=.183	1.0000 (32) p=.					
VULNER	-.0678 (297) p=.122	-.0350 (297) p=.274	-.0286 (265) p=.322	-.0385 (287) p=.266	-.0603 (312) p=.144	.2341 (312) p=.000	.1081 (312) p=.027	-.1230 (312) p=.015	-.1501 (312) p=.004	-.1027 (312) p=.035	1.0000 (312) p=.				
INST	-.0534 (260) p=.196	-.0166 (260) p=.395	.0524 (232) p=.213	-.0192 (232) p=.386	-.0612 (274) p=.157	-.0215 (274) p=.361	.0258 (274) p=.336	-.0697 (274) p=.125	.0780 (274) p=.099	.1385 (274) p=.011	-.0991 (274) p=.051	1.0000 (274) p=.			
TSM	-.0410 9297) p=.241	-.0498 (297) p=.196	.0030 (265) p=.480	-.0115 (287) p=.426	.0339 (312) p=.275	.0333 (312) p=.279	-.0841 (312) p=.067	.0333 (312) p=.279	-.0081 (312) p=.443	.2941 (312) p=.000	.0958 (312) p=.046	-.0926 (274) p=.063	1.0000 (312) p=.		
COG	.1078 (282) p=.035	.1180 (282) p=.026	-.0153 (252) p=.405	.0327 (253) p=.303	-.0218 (297) p=.354	.0511 (297) p=.190	.0347 (297) p=.276	-.0768 (297) p=.093	.0423 (297) p=.234	-.0970 (297) p=.048	.0580 (297) p=.180	.0234 (274) p=.350	.0101 (297) p=.431	1.0000 (297) p=.	
IMPATS	-.0948 (282) p=.063	-.0582 (282) p=.170	-.0007 (234) p=.498	.0595 (234) p=.182	-.0250 (276) p=.340	.0437 (276) p=.235	.0023 (276) p=.485	.0552 (276) p=.181	-.0470 (276) p=.218	.0583 (276) p=.163	-.0184 (276) p=.274	.0652 (274) p=.141	.3088 (276) p=.000	-.0398 (276) p=.258	1.0000 (276) p=.

LEGEND

ATTPER - Attention/Perception Error
JUDDEC - Judgement/Decision Error
SA - Situational Awareness
STRESS - Psychological Stress Level
MACHO - Macho (Hazardous Thought Pattern)
AUTHOR - Anti-Authority (Hazardous Thought Pattern)
RESIG - Resignation (Hazardous Thought Pattern)
IMPUL - Impulsivity (Hazardous Thought Pattern)

INVUL - Invulnerability (Hazardous Thought Pattern)
TEXTRO - Extroversion (Personality)
VULNER - Vulnerability (Personality)
INST - Achievement Motivation
TSM - Social Maladjustment (Personality)
COG - Cognitive Ability
IMPATS - Impatience (Personality)

LINK 1: REGRESSION MODELS FOR INDIVIDUAL DIFFERENCES TO PREDICT COGNITIVE PROCESSES

BASIC AND ADVANCED PHASES OF FLIGHT TRAINING

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION			
N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS			
Impulsivity/Impatience	.0010	.0001	.9914
Extroversion	.0005	.1775	.6738
Social Maladjustment	.0000	.0023	.9612
Achievement Motivation	.0021	.6660	.4151
Vulnerability	.0031	.9802	.3229
Cognitive Ability	.0001	.0589	.8084
PSYCHOLOGICAL STRESS LEVEL			
Impulsivity/Impatience	.0025	.7953	.3732
Extroversion	.0048	.1432	.7005
Social Maladjustment	.0001	.0341	.8535
Achievement Motivation	.0003	.09466	.7585
Vulnerability	.0013	.4232	.5158
Cognitive Ability	.0008	.26987	.6038
HAZARDOUS THOUGHT PATTERNS			
Anti-Authority			
Impulsivity/Impatience	.0016	.4997	.4801
Extroversion	.0091	2.8547	.0921
Social Maladjustment	.0011	.3446	.5576
Achievement Motivation	.0003	.09466	.7585
Vulnerability	.0548*	17.979	.0000
Cognitive Ability	.0023	.7203	.3967
Invulnerability			
Impulsivity/Impatience	.0019	.5992	.4395
Extroversion	.0026	.8214	.3655
Social Maladjustment	.0000	.0204	.8865
Achievement Motivation	.0052	1.6490	.2000

Independent Variable	r^2	F (1, 310)	p <
Vulnerability	Redundant Measure		
Cognitive Skills	.0017	.5311	.4667
Impulsivity			
Impulsivity/Impatience	Redundant Measure		
Extroversion	.0022	.6849	.4085
Social Maladjustment	.0011	.3437	.5581
Achievement Motivation	.0042	1.3287	.2499
Vulnerability	.0151	4.7600	.0299
Cognitive Ability	.0059		
Resignation			
Impulsivity/Impatience	.0000	.0013	.9713
Extroversion	.0043	1.3444	.2471
Social Maladjustment	.0070	2.2098	.1381
Achievement Motivation	.0005	.16557	.6844
Vulnerability	.0119	3.7322	.0543
Cognitive Ability	.0011	.3526	.5530
Macho			
Impulsivity/Impatience	.0005	.1648	.6850
Extroversion	.0084	2.6333	.1057
Social Maladjustment	.0011	.3568	.5507
Achievement Motivation	.0031	.9877	.3211
Vulnerability	.0036	1.1327	.2880
Cognitive Ability	.0004	.1409	.7076

Independent Variable	Beta	t-test	p <
MULTIPLE REGRESSION			
SITUATIONAL AWARENESS			
R-SQUARE = .0063, F (6, 305) = .3260, p < .9231			
Cognitive Skills	-.0188	- .328	.7428
Social Maladjustment	.0262	.410	.6819
Achievement Motivation	.0539	.923	.3567
Vulnerability	-.0310	- .536	.5925
Impatience/Impulsivity	-.0102	- .170	.8651
Extroversion	-.0429	- .698	.4856
PSYCHOLOGICAL STRESS			
R-SQUARE = .0063, F (6, 305) = .3260, p < .9231			
Cognitive Skills	.0317	.552	.5816
Social Maladjustment	-.0218	- .342	.7327
Achievement Motivation	-.0231	- .397	.6917
Vulnerability	-.0377	- .651	.5155
Impatience/Impulsivity	.0602	1.001	.3174
Extroversion	-.0166	- .271	.7866
HAZARDOUS THOUGHT PATTERNS			
Anti-Authority			
R-SQUARE = .0639, F (6, 305) = 3.47204, p < .0025			
Cognitive Skills	.0369	.663	.5000
Social Maladjustment	.0221	.358	.7208
Achievement Motivation	-.0025	- .045	.9638
Vulnerability	.2233	3.972	.0001
Impatience	.0411	.705	.4821
Extroversion	-.0775	- 1.299	.1949
Invulnerability			
R-SQUARE = .0326, F (6, 305) = 1.7155, p < .1169			
Cognitive Skills	.043903	.774	.4396
Social Maladjustment	.0188	.299	.7652
Achievement Motivation	.0674	1.170	.2428
Vulnerability	-.1477	-2.584	.0102*
Impatience/Impulsivity	-.0548	- .924	.3562
Extroversion	.029178	.481	.6310

Independent Variable	Beta	t-test	p <
	Impulsivity		
R-SQUARE = .02930, F (6, 305) = 1.5345, p < .1664			
Cognitive Skills	-.0663	-1.168	.2435
Social Maladjustment	.0167	.266	.7907
Achievement Motivation	-.0740	-1.283	.2006
Vulnerability	-.1224	-2.138	.0333
Impatience/Impulsivity	.0468	.789	.4308
Extroversion	.0301	.496	.6203
	Resignation		
R-SQUARE = .0239, F (6, 305) = 1.24776, p < .2817			
Cognitive Skills	.0300	.528	.5978
Social Maladjustment	-.0949	-1.502	.1342
Achievement Motivation	.0202	.349	.7272
Vulnerability	.1156	2.014	.0449
Impatience/Impulsivity	.0319	.535	.5927
Extroversion	-.0274	- .450	.6531
	Macho		
R-SQUARE = .01684, F (6, 305) = .8707, p < .5166			
Cognitive Skills	-.0112	- .197	.8440
TSM	.015303	.241	.8097
Inst.	-.06675	-1.149	.2515
Vulnerability	-.0550	- .955	.3406
Impatience/Impulsivity	-.0290	- .487	.6269
Extroversion	.09076	1.483	.1390

APPENDIX E

LINK 2: REGRESSION MODELS FOR COGNITIVE PROCESSES TO PREDICT PILOT ERROR: BASIC & ADVANCED PHASES

BI-VARIATE REGRESSION

N = 312, Missing Values = Mean Substitution

Independent Variable	r^2	F (1, 310)	p <
HAZARDOUS THOUGHT PATTERNS PREDICTING ATTENTION/PERCEPTION ERROR			
Macho	.0002	.0849	.7709
Anti-Authority	.0008	.2600	.6105
Invulnerability	.0000	.0098	.9211
Impulsivity	.0001	.0573	.8109
Resignation	.0020	.6348	.4262
HAZARDOUS THOUGHT PATTERNS PREDICTING JUDGMENT/DECISION ERROR			
Macho	.0000	.0171	.8960
Anti-Authority	.0001	.0567	.8118
Invulnerability	.0002	.0710	.7900
Impulsivity	.0014	.4430	.5062
Resignation	.0002	.0628	.8022

MULTIPLE REGRESSION

N = 312, Missing Values = Mean Substitution

Independent Variable	Beta	t-test	p <
HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .0012, F (4, 307) = .0947, p < .984			
Impulsivity	-.0029	- .043	.9657
Authority	.031368	.499	.6185
Macho	.019352	.302	.7628
Invulnerability	.0063	.090	.9285
HAZARDOUS THOUGHT PATTERNS TO PREDICT JUDGMENT/DECISION ERROR			
R-SQUARE = .0015, F (4, 307) = .1176, p < .9762			
Impulsivity	-.033162	- .488	.6257
Authority	.0109	.175	.8617
Macho	.0027	.044	.9653
Invulnerability	.00717	.102	.9191

APPENDIX F

HIERARCHICAL REGRESSION MODELS FOR COGNITIVE PROCESSES TO PREDICT PILOT ERROR

(Interaction Models)

Variables Entered on Step 1	BETA	t-test	p <
COGNITIVE PROCESSES TO PREDICT ATTENTION/PERCEPTION ERROR			
Level 1: R^2 = .22389, F (6,305) = 14.66*, p < .0000			
Invulnerability	7.2190	.012	.9908
Stress	.3120	5.982	.0000
Macho	-.0235	- .414	.6790
Situational Awareness	-.2882	-5.500	.0000
Anti-Authority	-.0048	- .086	.9314
Impulsivity	-.0235	- .392	.6957
Level 2: R^2 = .2241, F (7,304) = 12.54, p < .0000			
Variables Entered on Step 2 Situational Awareness * Stress	.0467	.285	.7762
P test for difference in R^2s Level 1 and 2 F (1,304) = 1.2, nonsignificant at p < .05			
Level 3: R^2 = .2632*, F (21,290) = 4.9, p < .0000			
Variables in the Equation at Step 3	BETA	t-test	p <
Invulnerability	.0562	.309	.7579
Stress	.3492	1.278	.2024
Macho	.3300	1.327	.1854
Situational Awareness	-.3382	-1.884	.0605
Anti-Authority	.3723	1.591	.1127
Impulsivity	.1169	.664	.5071
Situational Awareness/Stress	.0436	.254	.8000
Macho/Impulsivity	-.1458	-1.456	.1465
Invulnerability/Impulsivity	-.0216	- .230	.8184

Hierarchical Regression Models: Cognitive Processes to Predict Pilot Error (Interaction Models)

Cognitive Processes to Predict Attention/Perception Error

--continued--

Variables in the Equation at Step 3	BETA	t-test	p <
Macho/Anti-Authority	-.1642	-1.482	.1394
Macho/Invulnerability	-.1694	-1.608	.1089
Anti-Authority/Impulsivity	-.1980	-1.797	.0733
Anti-Authority/Invulnerability	.0140	.128	.8986
Stress/Impulsivity	.1390	.861	.3899
Stress/Invulnerability	-.1194	- .618	.5372
Situational Awareness/Anti-Authority	-.2023	-1.256	.2102
Situational Awareness/Impulsivity	-.0587	- .353	.7247
Situational Awareness/Macho	.1411	.885	.3767
Stress/Anti-Authority	.0172	.106	.9158
Stress/Macho	-.1763	-1.090	.2768
Situational Awareness/Invulnerability	.1550	.803	.4228

P test for differences in R^2's level 2 and level 3:
$F\ (14,290) = 1.08$, nonsignificant at $p < .05$.

COGNITIVE PROCESSES TO PREDICT JUDGMENT/DECISION ERROR

Level 1: $R^2 = .2959$, $F\ (6,305) = 21.36$, $p < .0000$

Variables Entered on Step 1	BETA	t-test	p <
Invulnerability	7.7890	.013	.9896
Stress	.3953	7.959	.0000
Macho	-.0431	- .796	.4265
Situational Awareness	-.2899	-5.808	.0000
Anti-Authority	-.0305	- .575	.5659
Impulsivity	-.0542	- .947	.3444

Level 2: $R^2 = .2965$, $F\ (7,304) = 18.30$, $p < .0000$

Variables Entered on Step 2	BETA	t-test	p <
Situational Awareness/Stress	.081190	.519	.6040

F test for the difference in R^2's between Level 1 and Level 2:
$F\ (1,304) = .2608$, non significant at $p < .05$.

Hierarchical Regression Models: Cognitive Processes to Predict Pilot Error (Interaction Models)

Cognitive Processes to Predict Judgment/Decision Error

--continued--

Level 3: $R^2 = .3263$, F (21,290) = 6.69, $p < .0000$

Variables in the Equation on Step 3	BETA	t-test	p <
Invulnerability	.0700	.402	.6880
Stress	.4396	1.682	.0937
Macho	.3965	1.668	.0964
Situational Awareness	-.2710	-1.579	.1154
Anti-Authority	.2819	1.260	.2087
Impulsivity	.1326	.788	.4316
Situational Awareness/Stress	.0594	.361	.7186
MIM Macho/Impulsivity	-.1323	-1.382	.1681
IIM Invulnerability/Impulsivity	-.0499	- .555	.5794
MAA Macho/Anti-Authority	-.1168	-1.103	.2109
MAI Macho/Invulnerability	-.0935	- .929	.3587
AIM Anti-Authority/Impulsivity	.0646	.613	.5406
SIM Stress/Impulsivity	.1641	1.063	.2886
SAI Stress/Invulnerability	-.1235	- .668	.5045
SAA Situational Awareness/Anti-Authority	-.0817	- .596	.5517
SIM Situational Awareness/Impulsivity	-.1327	- .833	.4054
SAM Situational Awareness/Macho	-.0755	- .495	.6208
SAA Stress/Anti-Authority	-.1132	- .725	.4693
SIM Stress/Impulsivity	-.1586	-1.025	.3063
SAI Situational Awareness/Invulnerability	.0879	.476	.6344

F test for differences between R^2's Level 2 and Level 3:
F (14,290) = .9130, nonsignificant at $p < .05$

APPENDIX G

HIERARCHICAL REGRESSION MODELS FOR INDIVIDUAL DIFFERENCES, COGNITIVE PROCESSES TO PREDICT PILOT ERROR

DV = Attention Perception Error

STEP 1:

INDIVIDUAL DIFFERENCES TO PREDICT ATTENTION/ PERCEPTION ERROR

$R^2 = .0233$, $F(6, 305) = 1.21$, $p < .2978$

Variables Entered on Step 1	BETA	t-test	p <
Vulnerability	-.0723	-1.259	.2090
Impatience	-.0727	-1.221	.2230
Cognitive Ability	.0956	1.677	.0945
Achievement Motivation	-.0467	- .807	.4201
Extroversion	-.0150	- .247	.8048
Social Maladjustment	-.0124	- .197	.8441

STEP 2:

INDIVIDUAL DIFFERENCES AND COGNITIVE PROCESSES TO PREDICT ATTENTION/PERCEPTION ERROR

$R^2 = .2461$, $F(12, 299) = 8.13$, $p < .0000$

Variables Entered on Step 2	BETA	t-test	p <
Vulnerability	-.0791		
Impatience	-.0951		
Cognitive Ability	.0784		
Achievement Motivation	-.0273		
Extroversion	-.0173		
Social Maladjustment	.0031		
Situational Awareness	-.2888	-5.52	.0000
Macho	-.0347	- .6900	.5489
Anti-Authority	.0047	.084	.9329
Stress	.3099	5.946	.0000

Hierarchical Regression Models for Individual Differences, Cognitive Processes to Predict Pilot Error
--continued--

Variables Entered on Step 2	BETA	t-test	p <
Impulsivity	-.0313	- .509	.6111
Invulnerability	-.0186	- .293	.7701

F test for difference in R^2's: $F (6, 299) = 48.81^*$, $p < .05$

DV = Judgment/Decision Error
STEP 1:
INDIVIDUAL DIFFERENCES TO PREDICT JUDGMENT DECISION ERROR

$R^2 = .0163$, $F (6, 305) = .8422$, $p < .5381$

Variables Entered on Step 1	BETA	t-test	p <
Vulnerability	-.0341	- .592	.5540
Impatience	-.0364	- .609	.5431
Cognitive Ability	.1056	1.846	.0658
Achievement Motivation	-.0201	- .347	.7288
Extroversion	.0040	.066	.9473
Social Maladjustment	-.0387	- .611	.5418

STEP 2:
INDIVIDUAL DIFFERENCES AND COGNITIVE PROCESSES TO PREDICT JUDGMENT DECISION ERROR

$R^2 = .3092$, $F (12, 299) = 11.15$, $p < .0000$

Variables Entered on Step 2	BETA	t-test	p <
Vulnerability	-.0326	- .634	.5263
Impatience	-.0614	-1.209	.2277
Cognitive Ability	.0850	1.750	.0811
Achievement Motivation	-.0017	- .035	.9718
Extroversion	.0021	.041	.9671
Social Maladjustment	-.0202	- .377	.7066
Situational Awareness	-.2891	-5.776	.0000
Macho	-.0458	- .827	.4092
Anti-Authority	-.0259	- .483	.6294
Stress	.3944	7.906	.0000
Impulsivity	-.0515	- .875	.3824
Invulnerability	-.0090	- .148	.8821

F test for the difference in R^2's: $F (6, 299) = 21.217^*$, $p < .05$

Hierarchical Regression Models for Individual Differences, Cognitive Processes to Predict Pilot Error

--continued--

DV = Attention Perception Error

STEP 1:

COGNITIVE PROCESSES TO PREDICT ATTENTION/PERCEPTION ERROR

$R^2 = .2230$, $F(2, 309) = 44.334$, $p < .0000$

Variables Entered on Step 1	BETA	t-test	p <
Stress	.3122	6.030	.0000
Situational Awareness	-.2850	-5.506	.0000

STEP 2:

COGNITIVE PROCESSES TO PREDICT ATTENTION/PERCEPTION ERROR

$R^2 = .24481$, $F(8, 303) = 12.27$, $p < .0000$

Variables in Equation Step 2	BETA	t-test	p <
Stress	.31104	6.013	.0000
Situational Awareness	-.2855	-5.525	.0000
Social Maladjustment	.0018	.033	.9740
Cognitive Ability	.0803	1.597	.1113
Achievement Motivation	-.0241	- .472	.6375
Vulnerability	-.0694	-1.368	.1722
Impatience	-.0944	-1.793	.0740
Extroversion	-.0221	- .412	.6809

F test for difference in R^2's: $F(6, 303) = 1.50$, not significant at $p < .05$

DV = Judgment/Decision Error

STEP 1:

COGNITIVE PROCESSES TO PREDICT JUDGMENT DECISION ERROR

$R^2 = .2917$, $F(2, 309) = 63.65$, $p < .0000$

Variables Entered on Step 1	BETA	t-test	p <
Stress	.3949	7.990	.0000
Situational Awareness	-.2831	-5.728	.0000

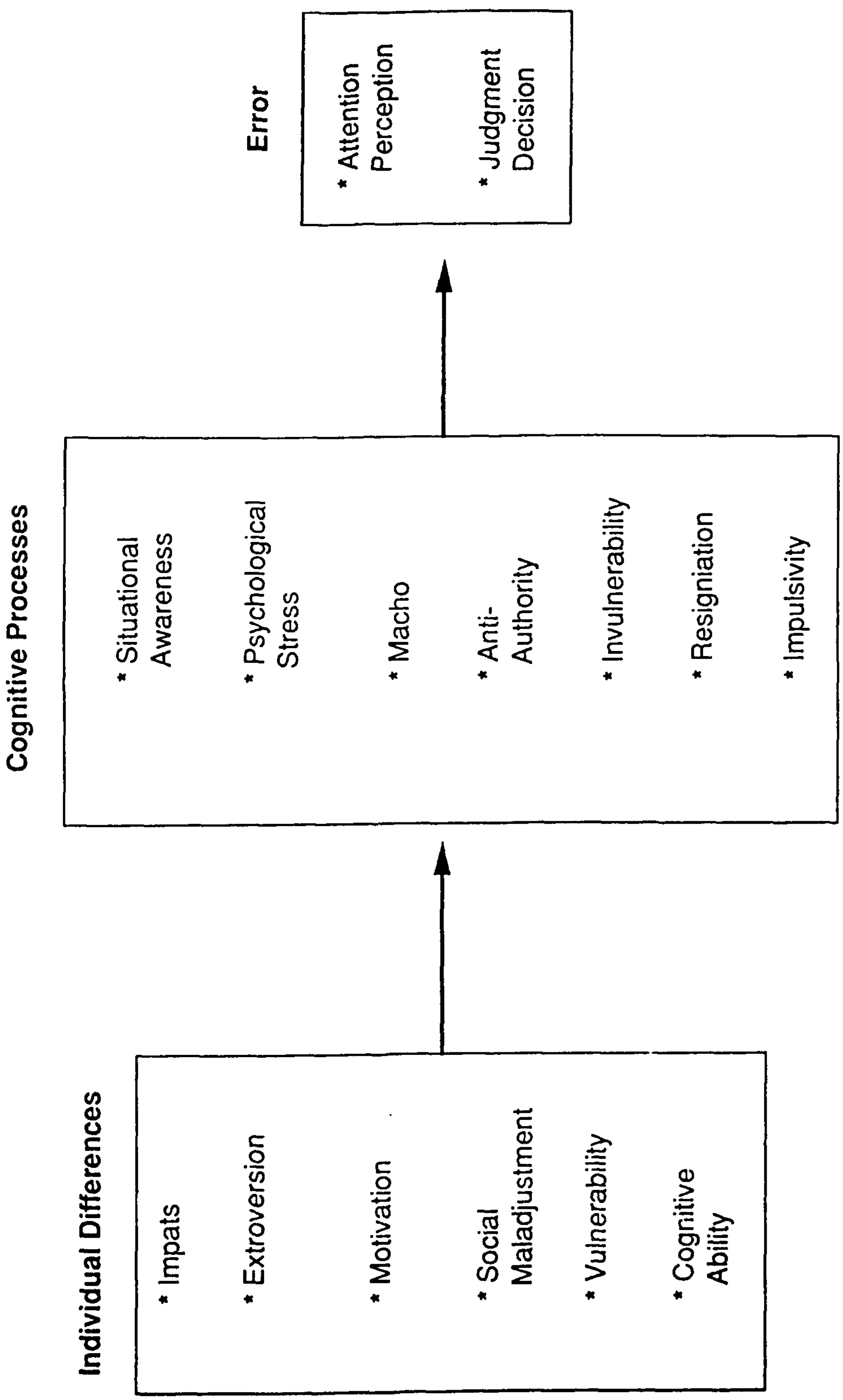
Hierarchical Regression Models for Individual Differences, Cognitive Processes to Predict Pilot Error

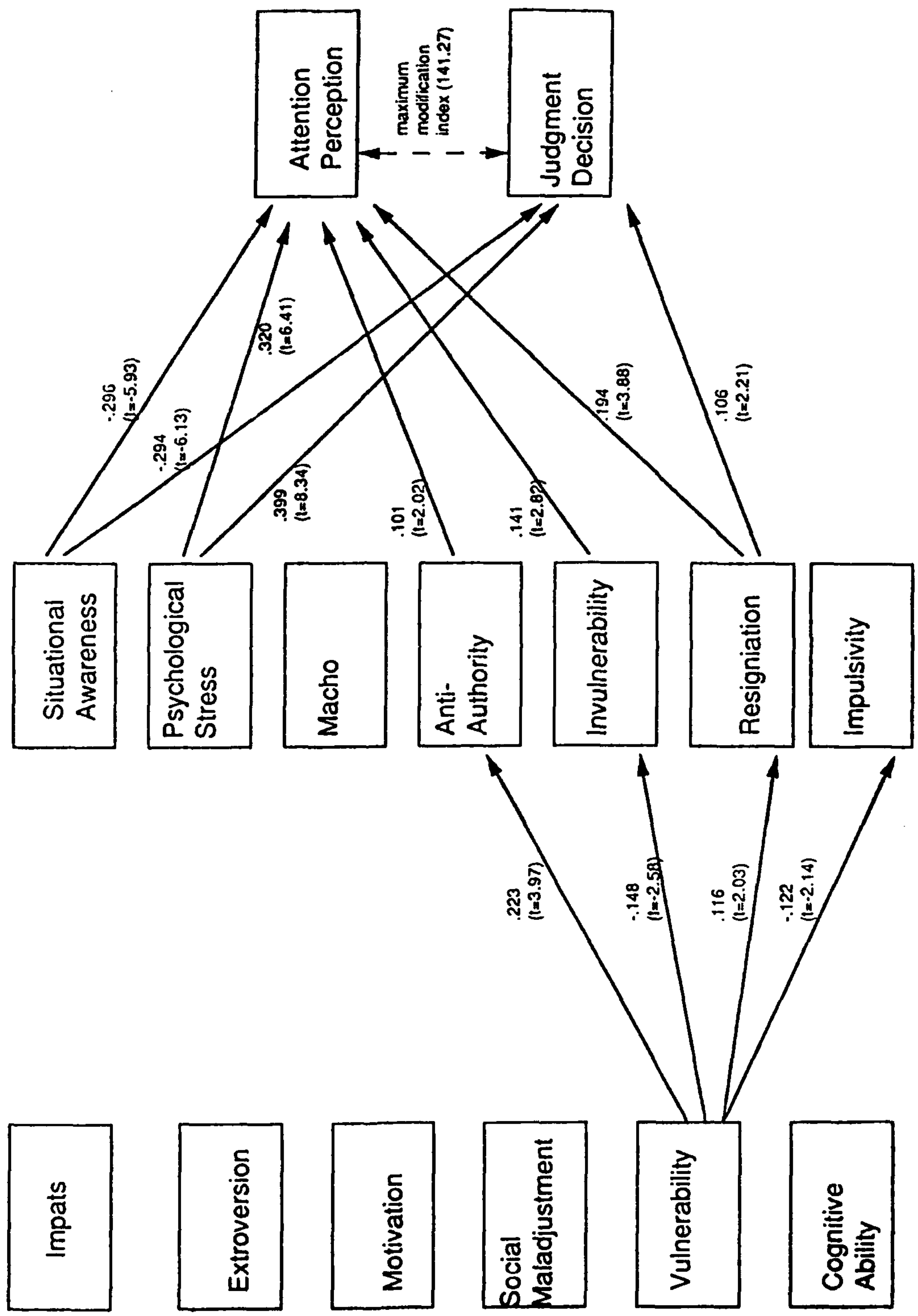
Cognitive Processes to Predict Judgment/Decision Error
--continued--

STEP 2: COGNITIVE PROCESSES TO PREDICT JUDGMENT DECISION ERROR			
R^2 = .3060, F (8, 303) = 16.70, p < .0000			
Variables in Equation on Step 2	BETA	t-test	p <
Stress	.3943	7.952	.0000
Situational Awareness	-.2830	-5.713	.0000
Variables in Equation on Step 2	BETA	t-test	p <
Social Maladjustment	-.0227	- .425	.6709
Cognitive Ability	.0877	1.820	.0698
Achievement Motivation	.0042	.087	.9311
Vulnerability	-.0280	- .577	5644
Impatience	-.0630	-1.249	.2127
Extroversion	-.0015	- .030	.9761

F test for the difference in R^2's: F (6, 303) = 1.04, not significant at p < .05

APPENDIX H


Individual Differences
* Impats
* Extroversion
* Motivation
* Social Maladjustment
* Vulnerability
* Cognitive Ability
Cognitive Processes
* Situational Awareness
* Psychological Stress
* Macho
* Anti-Authority
* Invulnerability
* Resigniation
* Impulsivity
Error
* Attention Perception
* Judgment Decision



Attention Perception
Judgment Decision
maximum modification index (141.27)
-.296 (t=-5.93)
-.294 (t=-6.13)
.320 (t=6.41)
.399 (t=8.34)
.101 (t=2.02)
.141 (t=2.82)
.194 (t=3.88)
.106 (t=2.21)
Situational Awareness
Psychological Stress
Macho
Anti-Authority
Invulnerability
Resigniation
Impulsivity
.223 (t=3.97)
-.148 (t=-2.58)
.116 (t=2.03)
-.122 (t=-2.14)
Impats
Extroversion
Motivation
Social Maladjustment
Vulnerability
Cognitive Ability

LISREL ANALYSIS

Measures of goodness of fit for the whole model:

Chi-square (df = 34) = 626.78, $p < .000$

Goodness of fit index = .868

Adjusted goodness of fit index = .533

Root mean square residual = .091

APPENDIX I

Link 1: Regression Models for Individual Differences to Predict Cognitive Processes

PHASE 1: BASIC FLIGHT TRAINING

Independent Variable	r^2	F (1, 310)	$p <$
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS			
Impulsivity/Impatience	.0006	.1923	.6612
Extroversion	.0003	.1023	.7493
Social Maladjustment	.0001	.0428	.8361
Achievement Motivation	.0000	.0012	.9723
Vulnerability	.0012	.3722	.5422
Cognitive Ability	.0006	.1937	.6601
PSYCHOLOGICAL STRESS LEVEL			
Impulsivity/Impatience	.0013	.4051	.5249
Extroversion	.0016	.5214	.4708
Social Maladjustment	.0000	.0022	.9623
Achievement Motivation	.0041	1.2813	.2585
Vulnerability	.0018	.5837	.4454
Cognitive Ability	.00102	.3158	.5745

Independent Variable	Beta	t-test	p <
MULTIPLE REGRESSION			
N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS			
R-SQUARE = .0028, F (6, 305) = .1455, p < .9898			
Cognitive Skills	-.0270	- .470	.6387
Social Maladjustment	.0087	.138	.8906
Achievement Motivation	.00194	.033	.9735
Vulnerability	.0324	.559	.5764
Impatience/Impulsivity	.0226	.376	.7070
Extroversion	-.021467	- .348	.7278
PSYCHOLOGICAL STRESS			
R-SQUARE = .0095, F (6, 305) = .4906, p < .8152			
Cognitive Skills	.0327	.571	.5682
Social Maladjustment	.0094	.149	.8817
Achievement Motivation	.0614	1.054	.2929
Vulnerability	-.0397	- .687	.4927
Impatience/Impulsivity	-.0436	- .727	.4676
Extroversion	.0316	.516	.6062

Link 2: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 1: BASIC FLIGHT TRAINING

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
Situational Awareness to predict Attention/Perception Error: $r^2 = .0634$, $F = 21.01$, $p < .0000$			
Situational Awareness to predict Judgment/Decision Error: $r^2 = .0643$, $F = 21.31$, $p < .0000$			
Psychological Stress to predict Attention/Perception Error: $r^2 = .1481$, $F = 53.89$, $p < .0000$			
Psychological Stress to predict Judgment/Decision Error: $r^2 = .2149$, $F = 84.89$, $p < .0000$			
HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
Macho	.0002	.0718	.7888
Anti-Authority	.0026	.8268	.3639
Invulnerability	.0028	.8721	.3511
Impulsivity	.0000	.00207	.9637
Resignation	.0002	.0803	.7770
HAZARDOUS THOUGHT PATTERNS TO PREDICT JUDGMENT/DECISION ERROR			
Macho	.0017	.5435	.4615
Anti-Authority	.0017	.0536	.8170
Invulnerability	.0018	.5677	.4517
Impulsivity	.0135	4.2559	.0399
Resignation	.0005	.1713	.6792

Link 2: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 1: BASIC FLIGHT TRAINING

--continued--

Independent Variable	Beta	t-test	p <
MULTIPLE REGRESSION N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, AND HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .1933, F (6, 305) = 12.1877, p < .0000			
Macho	-.0343	- .663	.5080
A Stress	.3479	6.661	.000*
Impatience	-.0733	-1.423	.1558
Vulnerability	-.0399	- .752	.4525
Situational Awareness	-.1944	-3.696	.0003*
Anti-Authority	.0263	.494	.6218
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, AND HAZARDOUS THOUGHT PATTERNS TO PREDICT JUDGMENT/DECISION ERROR			
R-SQUARE = .2668, F (6, 305) = 18.50, p < .0000*			
Macho	-.0582	-1.179	.2395
Stress	.4346	8.727	.0000
Impatience	-.0948	-1.930	.0545
Vulnerability	.0743	1.469	.1428
Situational Awareness	-.1941	-3.872	.0001
Anti-Authority	-.0440	- .866	.3874
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .1854, F (2, 309) = 35.174, p < .0000			
Psychological Stress	.3537	6.802	.0000
Situational Awareness	-.1956	-3.763	.0000
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT JUDGMENT/DECISION ERROR			
R-SQUARE = .2482, F (2, 309) = 51.00, p < .0000			
Psychological Stress	.4343	8.69	.0000
Situational Awareness	-.1846	-3.69	.0000

Link 2: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 1: BASIC FLIGHT TRAINING

--continued--

Independent Variable	Beta	t-test	p <
HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .0158, F (4, 307) = 1.239, p < .2943			
Macho	-.0174	- .307	.7593
Impulsivity	-.0923	-1.630	.1042
Vulnerability	-.0713	-1.223	.2222
Anti-Authority	.0709	1.216	.2250
HAZARDOUS THOUGHT PATTERNS AND JUDGMENT/DECISION ERROR			
R-SQUARE = .0171, F (4, 307) = 1.335, p < .2565			
Macho	.0418	- .738	.4613
Impulsivity	-.1173	-2.071	.0392
Invulnerability	.03789	.649	.5169
Anti-Authority	.0065	.112	.9113

Link 1: Regression Models for Individual Differences to Predict Cognitive Processes

PHASE 2: ADVANCED INSTRUMENTS FLIGHT TRAINING

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS			
Impulsivity/Impatience	.0001	.0551	.8145
Extroversion	.0002	.0674	.7953
Social Maladjustment	.0000	.0177	.8941
Achievement Motivation	.0074	2.3222	.1286
Vulnerability	.0045	1.4225	.2339
Cognitive Ability	.0001	.0386	.8442
PSYCHOLOGICAL STRESS LEVEL			
Impulsivity/Impatience	.0032	1.020	.3131
Extroversion	.0051	1.5991	.2069
Social Maladjustment	.0009	.2929	.5888
Achievement Motivation	.0037	1.556	.2832
Vulnerability	.0000	.0280	.8671
Cognitive Ability	.0020	.6357	.4259

Link 1: Regression Models for Individual Differences to Predict Cognitive Processes

PHASE 2: ADVANCED INSTRUMENTS FLIGHT TRAINING

--continued--

Independent Variable	Beta	t-test	p <
MULTIPLE REGRESSION			
N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS			
R-SQUARE = .0118, F (6, 305) = .6071, p < .7246			
Cognitive Skills	-.011927	- .208	.8353
Impatience/Impulsivity	.0054	.092	.9271
Extroversion	-.0061	- .101	.9198
Vulnerability	-.0652	-1.129	.2599
Achievement Motivation	.0849	1.459	.1457
Social Maladjustment	.0063	.100	.9204
PSYCHOLOGICAL STRESS			
R-SQUARE = .0157, F (6, 305) = .8136, p < .5599			
Cognitive Skills	-.0464	- .812	.4173
Social Maladjustment	-.0372	- .586	.5584
Achievement Motivation	-.0602	-1.037	.3007
Vulnerability	-.0130	- .277	.8208
Impatience/Impulsivity	.0736	1.230	.2195
Extroversion	-.0627	-1.025	.3064

Link 2: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 2: ADVANCED INSTRUMENTS FLIGHT TRAINING

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
Situational Awareness to predict Attention/Perception Error: $r^2 = .1489$, $F = 54.25$, $p < .0000$			
Situational Awareness to predict Judgment/Decision Error: $r^2 = .1423$, $F = 51.44$, $p < .0000$			
Psychological Stress to predict Attention/Perception Error: $r^2 = .1272$, $F = 45.19$, $p < .0000$			
Psychological Stress to predict Judgment/Decision Error: $r^2 = .1608$, $F = 59.41$, $p < .0000$			
HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
Macho	.0047	1.4895	.2232
Anti-Authority	.0017	.5503	.4587
Invulnerability	.0058	1.8234	.1777
Impulsivity	.0000	.0001	.9874
Resignation	.0022	.7033	.4023
HAZARDOUS THOUGHT PATTERNS TO PREDICT JUDGMENT/DECISION ERROR			
Macho	.0053	1.634	.1993
Anti-Authority	.0001	.0416	.8384
Invulnerability	.0164	5.177	.0236
Impulsivity	.0020	.6291	.4283
Resignation	.0016	.51856	.4920

Link 1: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 2: ADVANCED INSTRUMENTS FLIGHT TRAINING
--continued--

Independent Variable	Beta	t-test	p <
MULTIPLE REGRESSION			
N = 312, Missing Values = Mean Substitution			
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, AND HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .2101, F (6, 305) = 13.523, p < .0000			
Macho	.0275	.537	.5913
Impatience	.0045	.089	.9289
Vulnerability	-.0941	-1.789	.0747
C Stress	.2405	4.358	.0000
Anti-Authority	.0060	.115	.9087
Situational Awareness	-.2989	-5.393	.0000
SITUATIONAL AWARENESS, PSYCHOLOGICAL STRESS LEVEL, AND HAZARDOUS THOUGHT PATTERNS TO PREDICT JUDGMENT/DECISION ERROR			
R-SQUARE = .2445, F (6, 305) = 16.45, p < .0000			
Macho	.029813	.595	.5522
Impatience	.029416	.588	.5563
Vulnerability	-.1539	-2.990	.0030*
Stress	.2528	5.424	.0000*
Anti-Authority	.0505	.983	.3265
Situational Awareness	-.2769	9.146	.0000*
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .2004, F (2, 309) = 38.73, p < .0000			
Psychological Stress	.2454	4.462	.0000
Situational Awareness	-.2925	-5.320	.000
PSYCHOLOGICAL STRESS AND SITUATIONAL AWARENESS TO PREDICT JUDGMENT/DECISION ERROR			
R-SQUARE = .2198, F (2, 309) = 43.54, p < .0000			
Psychological Stress	.3010	5.542	.0000
Situational Awareness	-.2627	-4.836	.0000

Link 1: Regression Models for Cognitive Processes to Predict Pilot Error

PHASE 2: ADVANCED INSTRUMENTS FLIGHT TRAINING

--continued--

Independent Variable	Beta	t-test	$p <$
HAZARDOUS THOUGHT PATTERNS TO PREDICT ATTENTION/PERCEPTION ERROR			
R-SQUARE = .0107, F (4, 307) = .8368, p < .5026			
Macho	.0641	1.126	.2612
Impulsivity	.0165	.292	.7707
Vulnerability	-.0670	-1.147	.2521
Anti-Authority	-.023	- .397	.6961
HAZARDOUS THOUGHT PATTERNS AND JUDGMENT/DECISION ERROR			
R^2 = .0062, F (4, 307) = .4829, p < .7483			
Macho	.0652	1.022	.3078
Impulsivity	.0034	.050	.9599
Invulnerability	-.0302	- .430	.6679
Anti-Authority	-.0151	- .242	.8091

APPENDIX J

CHI-SQUARE PILOT PSYCHOLOGICAL STRESS LEVEL
BY EVALUATION PILOT
N = 213

CHI-SQUARE	VALUE	DF	SIGNIFICANCE
PEARSON	123.04495	105	.11016
LIKELIHOOD RATIO	129.12192	105	.05513
MANTEL-HAENSZEL	.49298	1	.48260

Minimum Expected Frequency = .019
Cells with Expected Frequency <5-115 of 128 (89.8%)

APPENDIX K

Regression Models for Evaluation Pilot Ratings to Predict Instructor Pilot Ratings of Judgement Decision Error

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
Evaluation Pilot Rating of Situational Awareness	.00794	2.48	.1162
Evaluation Pilot Rating of Psychological Stress	.0324	10.39	.0014

Regression Models for Evaluation Pilot Ratings to Predict Instructor Pilot Ratings of Attention Perception Error

Independent Variable	r^2	F (1, 310)	p <
BI-VARIATE REGRESSION N = 312, Missing Values = Mean Substitution			
Evaluation Pilot Rating of Situational Awareness	.0219	6.95	.0088
Evaluation Pilot Rating of Psychological Stress	.0566	18.60	.0000